THE VENTILATION, HEATING
AND MANAGEMENT OF
CHURCHES AND PUBLIC BUILDINGS

The Ventilation, Heating and Management of Churches and Public Buildings

By

J. W. Thomas, F.I.C., F.C.S.

Author of "Coal, Mine-Gases and Ventilation," etc.

Longmans, Green, and Co.

39 Paternoster Row, London

New York and Bombay

1903

PREFACE.

THIS is a practical treatise showing the prevailing errors in the ventilation of churches, halls, schools, and other public buildings, and pointing out how the faults can be remedied. The information bearing upon the effects of wind action, and the intermittent air currents in public buildings, was obtained by experiments, or elucidated in the course of the author's practical experience, and these, together with the studies in the physics of ventilation set forth, cannot fail to be of value to architects and builders, as well as to the managers and caretakers of public buildings.

The author has endeavoured to compress much practical matter into the smallest compass, and the scientific and technical information regarding the composition of the atmosphere, its impurities, etc., has been omitted because it can be obtained in any book on physics.

Portions of the treatise have been compiled especially to enable caretakers to make the best use of the ventilating appliances which they have to control, and as there is no book on the subject, and great need for such

information, it is hoped the matter provided will prove useful and instructive.

The illustrations are not intended to be complete drawings of the buildings in question, but are only given to show the air currents and other information in reference to the air supply.

LONDON, 1903.

CONTENTS.

LIST OF ILLUSTRATIONS.

CHAPTER I.

PHYSICAL LAWS BEARING UPON CHURCHES AND PUBLIC BUILDINGS.

TEMPERATURE.—In the majority of churches and public buildings there is no mechanical aid to ventilation, and during the summer months all that is done is to open the windows, and perhaps the doors during very hot weather. If the caretaker does his best to keep the air pure, and thinks fit to open all the apertures, there will be many in the audience probably who will object to any movement of the air, and these will endeavour to shut any air inlets in their neighbourhood. It is always best, therefore, to have the window openings out of the reach of the audience, and not to leave cords or other regulating appliances at their disposal.

The caretaker should carefully note the temperature of the air outside in the shade before he attempts to open the air inlets, in cold weather, and in spring and autumn this precaution is still more necessary. Where there are Tobin shafts near the ground, these cannot be opened wide if the air is 55° F. or less, and if they are, persons sitting close to them may take severe colds or suffer from neuralgia. Windows should not be opened widely unless the temperature is 65°, but at any temperature above 65° F., all the provisions for summer ventilation may be brought into play, and all Tobin shafts may be opened. When the temperature is 70° outside, or more, the doors afford further means of ventilation, and if any wind is moving, they may often be opened with most pleasant

and marked benefit in hot weather. In the next chapter this will be dealt with more fully, and illustrations given to show how the wind will act.

Where there is fair provision for sending warm fresh air into a building at the floor level, it will be well to begin to heat the air slightly when the outside temperature is less than 55°, and when it is 50° the air should be warmed in all buildings. During the autumn and early spring, the air is generally humid and raw, and by tempering it a few degrees it is rendered more fit to take up the moisture from the breath of the audience, and more amenable to upward movement, as the ventilating pressure of the building will be increased.

The caretaker will not be long in noting what temperature the audience likes best. He will soon get complaints of being too hot, if it is a degree or two above the usual, and if he goes *at once* to the thermometer and reads the inside temperature, and then without delay notes the temperature of the air outside, by the thermometer fixed on the north side of the church, or in the shade, he will obtain valuable information. Too much stress or importance cannot be attached to the necessity of providing a good thermometer for taking temperatures *outside* the building. It is the exception, rather than the rule, to do this, and hitherto a thermometer inside the building was the only one generally provided. The sudden increase or decrease of pressure, due to the rise or fall in temperature which so often occurs in this country, could then be noted, and precautions taken to prevent the close, unpleasant atmosphere which results from overheating air which is charged with moisture. The caretaker should endeavour to keep the temperature of the building at 58°-62° F., according as is best suited to the comfort of the audience, and this will depend upon the volume of warm air which gets into the building at the floor level. In order to maintain this temperature, much more heat will be required in damp, cold weather, and it is only possible to prevent extremes of heat and cold inside

the building by carefully observing and considering the temperature of the air outside. When it is a question of admitting unwarmed air, then the temperature of the outside air is equally important, and should be carefully taken before adjusting the inlets prior to the assembling of the audience. In like manner the temperature of the air outside should be the indicator for opening or closing the valves of any ventilators on the roof, or any other foul air exits that may be provided.

In this country it is usual to heat the churches and halls in cold weather to about 55° F. before the audience assembles. In America 70° F. is nearer the mark, but there is less moisture in the air than here, and more provision is made for removing the overclothing—men and women sitting in their seats dressed much as they are in their own homes. Under these circumstances, which might be imitated in this country with much comfort, it is possible to stand a higher temperature, but even then 65° will be the limit which can be borne without a feeling of enervation, in England. If men and women could be educated to dress so that the outer apparel might be removed in a church or public building, a much better chance would be afforded for increasing the ventilating power, especially during the autumn and spring months when it is so difficult to get any appreciable ventilating pressure, and when, at the same time, the opening of inlets for fresh air *unwarmed* is attended with unpleasant experiences. The higher the temperature the more aqueous vapour air takes up and retains, and the breath of the audience will not condense upon the walls and other surfaces if the temperature is 60° or more. It is assumed in saying all this that there is a reasonable volume of fresh air warmed coming into the building, but when that is not the case, as unfortunately it generally is, it is well to recollect that the germs evolved in breath can work best and decompose the organic matters present at a high temperature. On the other hand,

however, the higher the temperature the easier it is to ventilate the building, and to attain this, every effort should be made to provide and introduce more warmed air at the floor level. When this is done a temperature of 65° F. after the audience has been present half an hour will be agreeable. In our dwellings 65° F. is the most pleasant temperature when there is enough fresh air moving, and with proper provision in public buildings this temperature would be equally satisfactory.

The caretaker will always take due notice of the increase of temperature which will result from the bodies and breath of the audience. Not unfrequently 5° is allowed for this addition. In other words it is assumed generally that if 60° is the maximum the congregation will stand with their jackets and wraps on without grumbling, then the thermometer must not register more than 55° F. before the audience begins to arrive. When the caretaker reads the thermometer, which is frequently if not usually fixed against one of the walls, and finds it 55° F., he probably ascertains correctly both the heat of the walls on their surfaces as well as the heat of the air in the building. If he consults it after the audience has come in, the thermometer will show an increase of temperature, but if against a wall, it will not give so high a figure as it ought, because the air in the building has been heated quicker than the wall. For this reason the thermometer ought to be fixed or better hung from some projecting woodwork away from the outer walls. When 5° F. or more is allowed for the heating of the bodies and breath of the audience it shows a sad deficiency of inlet air, but in small buildings like mission halls which are crowded, a rise of nearly 10° may be expected during moderately mild and humid weather.

It is during such weather that the difficulties of the caretaker are greatest so far as trying to prevent overheating, but in many if not the majority of churches and public build-

ings when the temperature of the air outside is less than 35° it is found to be almost impossible to get the walls of the building warm enough to make it comfortable for the audience. The fire is lit on the Saturday evening—not infrequently early on Saturday morning—but, after firing with the utmost care, the building defies to be warmed sufficiently. The thermometer on the wall registers only 50° and will not go higher, and in some cases will not rise to this. Instead of this result the walls ought to be heated to 60° F. and should show this temperature when the doors were opened to admit the audience. The air in the building could be lowered by opening the doors and ventilators for a few minutes, and fresh air, mostly cold, admitted half an hour before the meeting. The reason why it is so difficult to warm the building when the air outside is below 35° may in some cases doubtless be due to want of sufficient heating power. But, generally speaking, it is owing to the cracks and fissures in the roof, and to the ill-fitting valves connected with the ventilators. It is not difficult to ascertain what is the matter and to point out the remedy. The advantage of heating the walls of the building rapidly and sufficiently hot needs little advocating. In churches and other buildings where the seats touch the outer walls and the audience sit close to them, the cooling effect of cold walls is unpleasant and injurious. In a large number of places of worship the seats adjoin the outer walls and are fixed thereto, and when the walls are cold, as they generally are, not only is there a cold douche of air descending continually, but the feet of all those in the side seats are rendered frigid by the cold current of air which moves towards the aisles so as to get to the down grating of the heater, or in the direction of any heating medium which may be near. If the inner walls of the building could be heated to 60° quickly, then there would be comfort for those sitting near them, and no moisture from the breath would be deposited on the walls. The upper part of the buildings

which have no ceiling and are boarded to the apex of the roof become cooled more quickly than the walls, and the consequence is that where the interior of a church shows only a temperature of 50° or 55° through whatever cause, the upper portion of the roof will soon become cooler when air from the outside is admitted with each person coming in, and, in very severe weather, cold currents may descend from the roof even when there are no perceptible cracks.

Where the electric light has been installed it is often thought that the fault of these downpours of cold air is due to the heat being less than was given off by the gas previously used, forgetting that no gas was lit for the morning service. Electric light or any other light, it is necessary to make the church comfortable, and this cannot be done in any other way so effectively and so conducive to health, as by raising the temperature of the walls and inside material to 60° before the time of assembly. Where the area of the top outlets of the building is too excessive, and not under control, it should be remedied, as the decrease in the coal bill would soon pay the cost, whilst the comfort which would follow would be greatly appreciated.

In some churches where the electric light is installed, gas is used above the lower bond of the principals of the roof to heat the upper stratum of air in the building, and recently burners of the Bunsen type have been fixed in some churches. The products of combustion where the flames play upon iron gauze are deleterious, and the ordinary white gas flame is much preferable. Some persons think that gas burnt in a Bunsen burner gives more heat than if burnt in a luminous flame, but, for equal volumes of gas, the total heat evolved is the same. Once the roof of the building was under control, and it was possible to heat the walls as suggested, *then it would be unnecessary to use gas to heat the air near the roof*, and no expense in reason should stand in the way of this result being attained.

VENTILATING PRESSURE.—When the air is warmed, the molecules of which it is composed are said to set themselves at greater distances—in other words, the volume of air involved expands and is consequently lighter bulk for bulk than air of a lower temperature. As air is one continuous ocean, it stands to reason that the lighter portion must always be lifted upward; so that in a building where the atmosphere is warmed artificially, there is a force on the outside always tending to raise the air upwards and cause circulation. According to the number and area of the inlets by which the outer air can gain access into a building will be the rapidity with which the internal air will be moved, and if these air inlets at the floor level permit an adequate volume of air to enter, then the ventilating force or power upon the building is sufficient for the time being. In churches and public buildings the greatest difficulty to obtain enough ventilating pressure is experienced in the autumn and late spring when the outer air is cold enough to cause a draught if a fresh air inlet is opened. If the air is about 55° outside and it is not possible to warm the air without making the audience feel hot, and the air is moist, the ventilating pressure of the building will be at its worst; and when, as will be shown presently, it is seen that three-fourths of the ventilating pressure may be used up, and most frequently is, in overcoming the friction the air encounters in getting into the building, very little pressure is left by which the air in the interior can be moved, and expelled through the outlets. When, in addition to the friction mentioned, it is pointed out that in the majority of churches and halls by far the largest volume of air which gains access to the building comes in at the top, and, by so doing, reduces the actual ventilating pressure available to force air in at the floor level on the outside, it will become evident, so far as so-called natural ventilation is concerned, that the usual appliances provided do not succeed in using the full ventilating power to the best advantage.

Some persons suggest that air inlets of the Tobin type would remedy this state of things. There are many churches where they are fixed, and in nearly all cases if persons sit close to them they are not opened at all in cold weather, because the flood of cold air is intolerable. There are buildings where they have not been opened for years. What is wanted is warm air at the floor level; and sham air inlets are worthless, and Tobin shafts are sham inlets when fixed close to where persons are sitting, and where they must be kept closed.

From what has been stated, it will appear evident that the ventilating power of a building depends upon the difference in density between the column of air inside a structure and a column of outside air of the same height. This force available for ventilating can be readily calculated. A church or hall is 50 feet high to the apex of the roof, and as there is no ceiling, it has 50 feet of headroom. The temperature of the air inside is 65° F., and that of the air outside is 50°. Fifty cubic feet of air at 50° F. weigh 3·89 lbs., and 50 cubic feet at 65° F. weigh 3·78 lbs. The difference in weight between the outside and the inside column of air is therefore ·11 lb. per square foot, or nearly 2 oz. pressure upon every square foot of air surface.

A hall with 30 feet of headroom has a ventilating pressure under similar conditions, $\frac{\cdot 11 \times 30}{50} = \cdot 066$ lb. per square foot. The hall with 50 feet of headroom has a ventilating pressure $1\frac{1}{2}$ times as great as a hall with 30 feet of headroom.

What is the meaning of the term ventilating pressure as applied to a public hall? It is simply this, that the outside air at the floor level of the hall will not only balance the air inside at the floor level, but will raise it, and force it upwards with a pressure equal to 2 oz. exerted upon every square foot of surface—the pressure increasing with the height of the building, a rise of temperature inside, or by the lowering of

the temperature of the outside air. When this theory of ventilating force became widely known, a somewhat natural, though mistaken deduction, was made. It was thought that if the ventilating force was exercised in raising the column of air in a building and propelling it upwards, what was wanted primarily was a free path or exit for the ascending air. It was said "there must be ample room to let the air out at the top, and then there will be ventilation". It did not strike the advocates of roof ventilation that there should be facilities afforded to let a volume of air into the building equivalent to that which should pass through the roof outlets, nor was any calculation made of the extra volume required because of the cracks and interstices in the roof. When ventilators were fixed, and there was much interstitial space in the form of cracks and fissures in the roofs of churches, it was found, as a first experience, that more fresh air *tried* to get in near the floor level through the doors and windows to supply the place of that which had so freely made its escape at the top. Then the seat holders near the doors and windows complained loudly of draughts and threatened to migrate; and to pacify these, the church authorities, without understanding what they were doing, ordered thick woollen strips around the doors, and the close adjustment of the windows, whilst ere long the inventor assisted with india-rubber tubing to prevent all draughts. The church authorities did not seem to realise that they were carefully excluding the outside air, and so failing to supply the necessary volume to pass through the ventilators and other outlets in the roof of the building. The consequence was that little air got into a church or hall at or near the floor level, and what did get in was not sufficient to move through the openings in the roof and through the ventilators with sufficient velocity.

Most people think that the outside ventilating pressure upon a building has done its work when the apex of the roof or the mouth of the ventilator is reached, and that a sort

of equilibrium exists there, so that no consideration is given to the fact that the pressure upon the air in the building is less than that upon the air outside, and that it is only the *velocity* of the air moving towards and through the top exits which prevents the outer air gaining admission into the building. Let that velocity fall below from 2 to 3 feet per second according to the height of the building, the simultaneous movement of the audience, as it sits down after a hymn, or a patriotic demonstration as the case may be, will be sufficient to upset the equilibrium, and cause down currents of cold air to enter through the roof exits. Owing to so many of the churches and public buildings having excessive top outlets when the air outside is very cold, and to there being so great a lack generally of fresh warm air admitted at the floor level, the velocity of the air passing outwards is too low, and at intervals of half a minute or more the roof outlets permit streams of cold air to descend, and give rise to those undulating and intermittent currents of air in large buildings which are so detrimental to good ventilation, and so unpleasant to the audience. If the building has no roof ventilator, and the velocity of the air as it escapes through the cracks and fissures in the roof is too low, streams of cold air enter in through the larger crevices until a point of internal pressure is reached when the outgoing air is expelled at too great a velocity to allow any further quantity of cold air to descend from the roof.

Let it be assumed that a church has 50 feet of headroom, and a ventilating pressure of 2 oz. per square foot of air surface. This pressure is most ample and will afford a velocity through a given opening at the apex of the roof of 10 feet per second without any difficulty, *if the pressure can be exerted upon the air in the building at the floor level.* But it cannot be exerted at the floor level, because the doors and windows have been most carefully adjusted. It is not forgotten that many buildings have fresh air inlets, and that the

pressure of the outer air is exerted upon them; but it will be found very frequently that they are either kept shut, or they are choked by dirt.

It is certain that not more than one-fourth, and often not more than one-sixth, of the total ventilating force in a church or public building is spent in raising the internal column of air, much of the other three-fourths being used up in forcing air through the crevices around the doors, windows, etc. The friction of the air so forced increases according to the square of the velocity, and when this fact is duly weighed, how fatal to the introduction of fresh air is the practice of closing every chink and crack by india-rubber tubing! For if by this proceeding one-half of the area of the cracks and crevices is cut off, the building will not only lose one-half the air which previously got inside, but actually three-fourths the original quantity. How necessary it is, therefore, to see that every inlet and grating is kept clean and open, and that there are sufficient apertures for air to get into the building; but it is fully realised that this is only practicable when the air which enters through such inlets is warmed as it gets into the structure.

If, however, three-fourths of the ventilating pressure is expended in forcing air into a building, it follows that the pressure which exists inside at the floor level must be less than that on the outside—in other words, there must be a partial vacuum inside the building, and, in the majority of instances, there is.

If the hall is low, and there is much outlet space at the top, then the tension on the inside air is practically nothing at intervals, and very little at other times. But, generally speaking, there is a very appreciable tension, or partial vacuum in churches, chapels and halls, notwithstanding the leakage from high windows and from the roof. It is this roof leakage which is so mischievous, and so frequently ignored probably on account of its being little understood. It is generally

agreed that the air which gets in at a high window or through the roof is only forced inwards at that point by a pressure equal to the remaining air column in the building. Let it be assumed that a church is 50 feet high from the floor to the apex of the roof. Through the loss of a slate a volume of air issues into the building 10 feet below the apex of the roof. If the ventilating pressure in this building is 2 oz. upon every square foot, then the ventilating force through which air will enter at 10 feet below the apex of the roof will be $\frac{10 \times 2}{50}$ or two-fifths of an ounce of ventilating pressure upon every square foot, and this is a correct measurement of the ventilating pressure at that point.

But there is a factor of much importance which has not been considered, and which has, probably, never been previously explained. If what has been stated before is correct, and three-fourths of the ventilating power has been used up in forcing air through the crevices around doors and windows, then less than one-fourth of the difference in density due to the heated atmosphere has been added as pressure to the air inside the building, because a portion of the internal pressure is used up in giving velocity to and in overcoming the friction of the air passing through the outlets in the roof. In a church 50 feet high, the difference in pressure between the air inside the building and that on the outside after the outer pressure was used up in trying to force air into it, would represent the difference between the weight of a column of internal and external air about 37 feet high—*i.e.*, $\frac{37 \times 2}{50}$ or about $1\frac{1}{2}$ oz. per square foot. If, therefore, the air entering the roof 10 feet from the apex as already noted follows the law of falling bodies and streams to the floor of the church, it would exert a pressure equal to a height not of 10 feet but of 37 feet. This is assuming, of course, that the cold air streaming in would fall as a solid body and not

separate much and become warmed as it fell, and so lose some of its pressure. In those buildings that are high and where there are two outlets, it is the most natural thing possible that one ventilator should send a flood of cold air downwards in order to neutralise the difference of pressure between the outer and inner atmospheres, and the additional volume of air so admitted and partially warmed would be forced through the other ventilator at a high velocity. The ventilating pressure which has been calculated for the church 50 feet high, is the low pressure obtained during the spring and autumn months of the year when the air outside is about 50°, but during very cold weather in winter that pressure will be much increased. In the spring and autumn months less is heard of down draughts, because the air outside is not very heavy, but once the temperature falls to 35°, or less, the difference of pressure left in the building, after the outer atmosphere has expended its power in forcing air into it, would, in many instances, be as much as 3 oz. per square foot, were it not for the volume of air which pours down from the crevices in the roof and from the other roof outlets. Unless a corresponding volume of air is admitted at the floor level, it shows how baneful to ventilation are the large top exits, some of which are not exits in cold weather, but inlets. *From the above deductions it is clear* that three-fourths of the ventilating pressure is generally used up in friction due to the small apertures through which air is forced into a building. Whilst this is true in most cases, great care must be exercised that the air is not introduced through apertures which are too large, otherwise, as will be seen in the next chapter, the action of the wind will lead to unpleasant results.

The influence which the elastic properties of air exert upon the internal ventilation of large buildings, and how alternating air-currents [1] are formed, will be next considered. When a

[1] The substance of what follows was communicated to the British Association at the Glasgow Meeting, 1901.

building has too much outlet space but no ventilator fixed either upon the ridge or within the side of the roof, the air gathers in the portion which is ceiled either at the first or second tie of the principal. In nearly every case a grating or gratings communicates with the air space enclosed, and if the building is high, a flood of cold air will pour down through the one which offers the least resistance. The point of least resistance is usually determined by the form of the building itself, although during strong winds the circumstances may be somewhat altered. The easiest path for the upward movement of air is naturally in the centre of the building free from walls and other obstructions, and the grating generally found to have an upward current passing through it is the one in the centre. The position of the doors may make a difference in some cases, but this is the natural result. If there are three ventilators on the roof, or if there is much free way through cracks and fissures, it often happens, especially where the entrance doors face the preacher, that the cold air descends most upon him; least in the centre of the church, and then in increasing quantity at the end where the entrance is. If the door is on the side of the church, the centre of the building has usually the least down draughts, unless the headroom is very considerable, the two ends being more equally and generally affected. This is how down draughts occur, and the difference in density between the air outside the building and the air inside is sufficient to account for these. But persons who frequent large churches and halls cannot fail to notice that where there are severe down draughts, there are other and equally unpleasant experiences. The cold wave of air is followed by a hot and oppressive atmosphere, which may last for a few or several seconds, then there is a period of slight relief followed by one of greater oppression, and subsequently the cold wave appears again. At intervals, these experiences are repeated, and form what are styled "alternating air currents".

Several years ago, the author proved the existence of such alternating air currents experimentally, and the cause of the *alternations*, in attending to the ventilation of a large public hall. The hall was very high, 40 feet to the ceiling, and had three sun-burners with tubes passing through the apex of the roof, and these tubes were surrounded by large cylinders for the exit of air from the building. Being desirous of measuring the actual difference of pressure of the air outside a building and the air inside, and thinking so high a hall would afford a good opportunity, a pressure recording instrument was fixed to see what the difference was. The temperature outside registered only 30° F., and the difference of pressure was naturally considerable, but, surprising as it was, at intervals of about a minute, the pressure inside the hall increased until it was not only equal to that of the air outside, but actually very *appreciably above it.* The building was well heated by hot water coils for the experiments, and every inlet was opened to the full. The pressure indicator was examined frequently and always with the same results. Taking the point of the least internal pressure as the first observation, it took about half a minute to reach the point of highest internal pressure, and rather less than half a minute after to reach the point of least pressure again. The first five seconds after the least pressure was reached, there was a gradual rise, followed by double such an interval of more rapid increase; then there were a few seconds of lesser increase, followed by a lengthened period during which the instrument remained almost steady. When the reduction of internal pressure began again, much cold air still descended, and there were ten or more seconds during which the reduction in pressure was gradual, then, for about half that period, a very rapid decrease occurred, followed by several seconds when the instrument was steady and almost stationary at the point of least pressure.

From the results of these and subsequent experiments, it

was found that when the atmosphere in a large building is very hot, the period of least pressure referred to is extremely trying, because the quiescent foul air is re-breathed, and the effects are increased probably by the electrical conditions due to the sudden expansion of the air; but when the fresh air commences to pour down, the oppression decreases until the point of greatest pressure is nearly reached. During the period of comparative rest at the highest pressure the dense air is being heated and expanded, and, until it begins to move upward, the breath of the audience is inhaled, and a feeling of oppression experienced. When a large volume of air descends, the waves flow over one portion of the building, and, owing to the sudden compression, not much of the fresh air reaches the level of the sitters, so that during the periods of greatest pressure the air is so beaten back as to become very foul, whilst during the period of least pressure the conditions are even worse.

A point of much interest is the fact that, owing to its elastic properties, the denser and colder air descended and compressed the layer underneath so much by falling through so great a height, that the pressure due to the density and *velocity* of the descending current upon so elastic a body gave rise to a *greater pressure inside the building than there was outside.* The coldness of the night, and the heating of the building inside, considerably helped these results, which the author never succeeded in getting in a low building. It was found frequently, however, that alternating air currents at their greatest pressure in high buildings in winter, beat back the inlet currents near the ground level, and in several instances an anemometer held in a narrow opening in a doorway leading to a church turned rapidly inwards indicating an up current, and then stopped and subsequently turned outwards during the periods of greatest internal pressure.

In the hall mentioned, there were a number of hot water coils near the outer walls with air inlets behind them. These

were tested with a very delicate anemometer, and during the period of greatest internal pressure some of the air in the building was forced out through the fresh air inlets, the great elasticity of the air doubtless having much to do with this.

In high churches having much outlet space in the roof and heated by hot water pipes, where alternating air currents abound in winter, it often happens that the fresh air inlets are checked and act as outlets during the period of greatest pressure; and when the period of reduced pressure commences they act as inlets again. When, however, the period of *rapid* decrease in pressure is reached, and the temperature of the air outside is very low, such a deluge of cold air ascends the gratings that the audience cannot stand it, and the consequence is that the inlets are shut altogether, and the ventilation of the building considerably impaired.

Where sun-burners are fixed underneath ventilators, and air shafts passing through the roof, it is not very difficult to watch the progress of down draughts and intermittent air currents, by carefully observing how the gas flames are affected. If there is a continuous and powerful up current, the flames point upward and become elongated. If the up current is violent, as it is where powerful alternating currents are formed in consequence of the top exit space being much too great for the low temperature of the air outside, it may be, as it was in the case of the public hall to which reference has been made, that the luminosity of the gas is more or less lost owing to the flames being rendered blue by the quick movement of the air. If the building is high and has two such sun-burners and much top outlet space, then, in cold weather, the flames of the two burners will appear irregular, showing that there is sometimes an up current and sometimes a down draught. In less cold weather it will be found that one of the sun-burners will show a continuous up current, and the other admit a more or less severe downpour of cold air at intervals, according to the frequency with which the doors are opened,

and the temperature of the air outside. A careful observer can tell from the flames how matters stand, but, unfortunately, the tubes from the sun-burners are not responsible for all the mischief. Then again, the majority of churches and public buildings are not furnished with sun-burners, and those which are, are rapidly becoming fitted with the electric light. In order to try and prevent down draughts, it not unfrequently happens that when the electric light has been installed the sun-burners are used to cause an up current. This is a great waste, and can be obviated without much difficulty.

It must not be forgotten, therefore, that in high buildings the top outlets require to be under perfect control, otherwise, when a reasonable supply of fresh air has been provided near the floor level, this supply will be rendered inoperative by the action of the alternating air currents in the building. Excessive top outlet space is always the cause of the mischief, and, when the greatest pressure is formed inside the building, no air can come in at the bottom. When the least internal pressure occurs, the suction on the air inlets near the floor level is *so great, and so much greater because of the elastic nature of the air*, that in spite of the best provision for warming the air as it enters the building, the fresh air will pass in so rapidly that persons cannot endure it in very cold weather, *and the air inlets will be shut.*

By careful observation, it is alike possible and interesting to note the form which the waves of air assume under the influence of intermittent air currents. These waves will vary in length and depth according to the height and other dimensions of the building, as well as upon the position from which the greatest downpour of cold air comes. The church which is described in sequel, and shown in Fig. 19, p. 85, having one large outlet above the dome, is so high and spacious that the cold air falling and giving rise to intermittent air currents compresses the lower layers of air and forms waves like those shown in Fig. 1. These waves have

horizontal undulations, and their crests, for the most part, are not high. The falling cold air compresses the layer underneath, and at the same time spreads outwards as it falls. Fig. 1 represents the waves formed by the cold air streaming through the opening in the top of the dome. A few seconds later, and the falling air has compressed the

FIG. 1.

atmosphere in the building to the utmost extent, and immediately afterwards the cold air becomes heated, expands, and gives rise to the upward movement, when the position of the crests of the wave will be, naturally, reversed. The doors are opened frequently to admit persons, and the pressure of the air coming in presses against that just above the

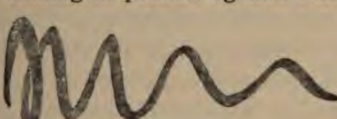


FIG. 2.

level of the seats and forces it in the direction of the pulpit, P. When this occurs, the lower waves during the downpour of cold air become shorter, and have much higher crests in consequence of the forward motion, and the form of the undulations somewhat resembles Fig. 2—the short waves with the high crests being next to the pulpit end.

The church mentioned in Chapter V., and shown in Fig. 16, has a considerable down draught from one of the ventilators, whilst there is a strong up current through the other. The movement of the air is chiefly from one end of the building to the other, or pulpit end; but there is a lateral movement induced by the circulation of hot air, and in this case the waves of the intermittent air currents approach in form to Fig. 2.

In theatres and buildings which are very high compared to the width or diameter of the free air space or uninterrupted column of air, and where a huge chandelier is fixed under the dome at the top, it frequently happens that the outlet space is

FIG. 3.

very excessive when compared with the area ot the inlets, and alternating up and down movements of the air are very marked. These movements may not inaptly be compared to those of a spiral spring, Fig. 3, when it is compressed and released, only that the waves would be more horizontal at the points facing those portions of the building where the chief open spaces occurred.

Owing, however, to the elastic nature of the air, the wave movements are not mechanical, but responsive to the various local influences which surround them. It will be evident from the illustrations that the waves must vary in length and form according to the circumstances mentioned.

CHAPTER II.

THE ACTION OF WIND UPON VENTILATION.

THE importance of wind action in causing the movement of air has been long recognised and appreciated, but the value of the aspirating powers of the wind in inducing ventilation in public buildings is much overrated. This overrating is due to a variety of causes.

(1) As to the average velocity of the wind. Where observations of wind pressure are taken, it is usual to fix the anemometer in the most open space where the wind has free play, and also to set the revolving vanes as high as possible. Observations of this kind are comparative, and of value for making tables, but they throw no light whatever upon the manner in which the wind acts at the top of a building surrounded by other houses, or the velocity with which wind travels over such a building. Recent experiments with kites fitted with recording instruments, have shown that the velocity of the wind is generally twice as great at the altitude of 1,000 feet as it is in the open country near the ground level. Again, the friction caused by the wind passing over buildings is so great that it is scarcely possible to demonstrate it accurately. Those who stand in an open square or park near houses over which the wind blows, will soon learn how greatly the velocity of the wind is accelerated the moment it leaves the roofs of the houses.

If the average velocity of the wind at the recording station

is eight miles per hour, it will be safe to assume that in London and large towns it does not exceed four miles per hour as it sweeps over the roofs and housetops. Furthermore, it must be noted that the average velocity of the wind is largely increased by the equinoctial gales, and these winds are usually very choppy and gusty in the extreme. Nothing tends so much to interfere with steady ventilation and to overturn the mechanical and other arrangements of the inlets and outlets as do these winds. After, therefore, deducting the pressure due to winds which are injurious, the average aspirating power during the periods of the year when it would be most serviceable is a small and very uncertain quantity.

(2) The second reason why the value of wind aspiration by the aid of pneumatic cowls and ventilators has been overrated is because air is one vast ocean, and, in all cases of ventilation, no matter how small or how large the building is, the air is one continuous body or mass. The connection between the air in a building may be so minute that it is just the chinks around the doors and windows, and if the atmosphere in a building is compared to a promontory, then it is united to the mainland by the narrowest isthmus, but there is such an isthmus, and all the physical effects which occur as the result of wind action upon the main body of the air outside are more or less communicated to the air inside the building. The larger the openings—the inlets and outlets—the more the wind effects will be felt inside the building, but the chief point to notice is that the aspiration of the wind may be, an[illegible] often is, greater upon the inlets near the floor level than i[illegible] upon the ventilators above the roof. In the case of a ch[illegible] upon a hillside with buildings above it on the side [illegible] hill immediately facing the wind, the wind effects [illegible] mouth of the ventilators on the roof will be reversed [illegible] of aspiration there will be increased pressure, which [illegible] force air outside down into the building. The [illegible] [illegible]ch from which, in this case, air is taken to su[illegible]

inside, adjoins a street crossing the brow of the hill, but there is also a free space adjoining the church itself. The wind sweeping along this street aspirates powerfully on the inlets at the ground floor level, the result being that if the ventilators on the roof are open they act as inlets, sending volumes of air into the building at every gust of wind, causing such violent down draughts that the ventilators on the roof must be kept closed. In this case, and there are plenty of churches so situated, the wind effects are baneful, and the *so-called pneumatic, or air-pump ventilator, is a self-acting down draught producer.*

(3) The third reason why the value of the aspirating powers of the wind in inducing ventilation has been so greatly overrated is because the physical laws bearing upon the atmosphere are not sufficiently understood. The law which governs moving bodies not only applies to wind, but the effects are greatly complicated by the *elastic properties* which air possesses.[1] The wind blowing over the tops of houses across a street, not only draws air out of the street, but reduces the pressure upon the air in the street by expanding it with a pull equivalent to the force which gives rise to the velocity of the wind. The air in the street (which must have no outlet in this case) may be compared to the fixed end of an elastic thread, and the effects of the wind blowing over the buildings across the street, to a person's fingers pulling at the free end. As long as the velocity of the wind continues, the air in the street is expanded and drawn out like the elastic. When a gust of wind ceases, the expanding effects cease also, and the air contracts to its original bulk like the elastic does when it is released.

It is this elasticity, this sudden expansion and contraction, which requires to be understood. It is either unknown to the ventilating engineer, or else it is ignored by him, but, all the

[1] The substance of what follows was communicated to the British Association at the Bradford Meeting in 1900.

same, it is the most potent factor which increases the difficulty of ventilating buildings, and which renders the aspiration of the wind not only valueless under existing conditions, but absolutely unmanageable. It is no secret to the architect, the ventilating engineer, or even to the public, that what is wanted for churches and halls of assembly is fresh warmed air introduced at the floor level, and that buildings are most sadly deficient in this particular. It is equally well known that cold air inlets cannot be endured when the temperature is low, the consequence being that there is much less pressure inside the building than there is outside. Let it be assumed that the building having the self-acting pneumatic ventilators on its roof is situated in the best position possible for the wind to act upon them—the hall is upon the top of a hillock, the roof is much higher than those adjoining, and the wind sweeps over the open country with great aspirating force. The consequence is that the air inside the hall is drawn out—expanded, like the india-rubber thread mentioned above, and, by reason of the large outlet space on the top, and the small inlet space at the bottom, the air in the building is greatly expanded during the time a gust of wind is blowing; but the moment any lull occurs in the pressure of the wind, or the gust ceases, the air in the hall, like the elastic thread referred to, contracts, and as very little air gets in at the floor level, and that little under much friction, the air in contracting draws a supply, to fill the partial vacuum, along the lines of the least resistance, which in this case is *down the ventilator*. It will be seen, therefore, that if a building is situated in the best position for ventilators which are designed to aspirate by wind action, *and they do aspirate*, the effects are as inimical to good ventilation as it is possible to be. The effects to which I have referred were proved by experiments and demonstrated with a large model, and there is no doubt that the ingenuity of the ventilating engineer should be directed to shielding the mouth of a ventilator from wind

action, rather than trying to devise methods to utilise the action of the wind so as to aid the ventilation of churches and public buildings.

It is claimed, sometimes, that certain roof ventilators have a peculiar property of inducing air currents through them, as it can be shown by an anemometer, or any delicate means which demonstrates moving air, that even in weather so calm that no wind can be detected, there is air travelling through the tubes of such ventilators. There is no reason to deny this statement that air ascends ventilators when no wind is blowing, but it should be understood that such will be the case with *all ventilators*, however little or great their pretensions, whilst the open tube will still be found the most effectual in this particular. It is easy to explain why a current of air generally, fitfully or intermittently, ascends the ventilators in empty buildings when no audience is present. In winter the building is warmed at intervals and the walls retain their heat for some time, so inducing a current to circulate. The inside of the building is sheltered, and warmed by other buildings somewhat. The building whether in a hollow, on level ground, or on a hill top, is influenced by the flowing wind, more especially as the roof outlets greatly exceed the ground inlets in area. In summer the roof is heated by the sun, and a current of air is caused to ascend the ventilators in consequence.

Ventilators, *which are called self-acting, do not cause these induced currents*—it is the physical effects due to heat and the general aspiration of the wind, which form them—*and they are formed whatever kind of ventilator or open tube is used upon the roof.*

When a current of air is blown right across the outlet plates of the models of pneumatic, self-acting, or pumping ventilators, as is usually done by those who sell them, they exhibit considerable aspirating powers, but the pressure of the breath employed represents the blowing of a *violent gale.*

There is nothing like ocular demonstration to convince the public, and when one sees the cotton wool ascending in the tube of the model, it *does* look as if the ventilator must be effective. To test the value of such a model, a strong current of air measuring a foot square, produced by a fan or blower, should be directed against it, when it will be found that the current, like the wind, is neither discriminating nor obliging enough to blow just at the right point or upon the right side of the exit plates; but full against the openings between the plates immediately fronting the wind, and so the suction or aspiration is neutralised. After testing the value of the model in the current of air suggested, the *head* of the ventilator should be removed, and the air current directed over

FIG. 4.

FIG. 5.

the end of the open tube. On comparing the aspirating effects of the air current upon the open tube with those produced by the air pump ventilators there will be a most striking difference in favour of the open tube, amounting from two to five times, according to the form of the pneumatic ventilator employed, and to the shape of the end of the open tube. If the open tube is cut off like Fig. 4, and the wind blows against the left side, the aspirating effects are nearly twice as great as when it impinges against a pipe, Fig. 5, with a mouth level all round. An ordinary revolving lobster cowl is four times as effective as the best ventilator of the air pump variety for inducing a current of air by the wind, but either is capable of upsetting the ventilation of a closed building; and, as before stated, wind suction is too irregular

and uncertain, and often too violent, to be of any practicable use in ventilating churches and public buildings.

It has been stated that the extracting efficiency of an outlet ventilator depends upon the surfaces exposed to the aspiration of the wind, and not so much upon the diameter of the tube itself. Such a statement is most misleading. The volume of air aspirated by the wind must always be inversely as the resistance or friction encountered, and as the friction increases greatly with every decrease in the diameter of the tube the volume aspirated does depend primarily upon the diameter of the outlet shaft.

By cutting off a tube slantwise at the top as above, Fig. 4, it is seen that the great friction which the air encounters against the lip of the tube, Fig. 5, has been removed, and nearly double the air will be aspirated in consequence. The result is due to the decreased friction, and the extra volume aspirated is not *proportional to the length of the slant*, but to the lesser friction which the air encounters.

In the turret form of extractors *the friction is not reduced in the head itself by increasing the height and exposing more aspirating surface*, so the suction power of such a ventilator must be proportional to the diameter of the inside tube and the friction encountered in the head. The fact that the wind aspirates so much more powerfully upon an open tube than by means of any extracting ventilator, no matter how much surface is exposed, shows how great is the friction which the wind encounters in aspirating the air through the head of the ventilator.

What the condition of the atmosphere in large towns would be if there were no wind it is difficult to tell, and, during the summer and hot weather, the ventilation of houses and public buildings is very largely dependent upon the movement of the air due to the breezes and currents formed through the unequal heating of the earth's surface by the sun's rays.

The ventilation of churches and public buildings, in

summer, requires the attention and observation of the caretaker to be exercised to the fullest extent if he is going to accomplish his duties in a successful manner. All that is usually attempted, however, is to open certain windows or movable panes all over the building, and, having done this, it is often thought that the ventilation is as complete as can be attained under the circumstances. This is not the case, however, and, just as the careful noting of the temperature of the air outside a building is the most effectual precaution in attending to winter heating and ventilation in churches, etc., so is the appreciation and knowledge of small wind currents of the greatest importance to the caretaker in keeping the atmosphere of his building in the best condition during the summer time. Furthermore, he should note just what the wind effects will be upon the windows, doors, and other outlets or inlets of the structure according to the direction from which the wind blows.

The church or public building which has a delicate wind vane will furnish him with the direction of the wind, and he will be able to know if the force is appreciable from the movements of the vane. All new buildings ought to be so provided, but an intelligent man who once realises the value of air currents, properly directed, will soon discover the quarter from which the wind blows.

What the effects of the wind will be upon the doors, windows, ventilators, etc., is a different matter, and one which has not been previously determined. The author made a series of experiments extending over some years, and the results obtained were partly communicated to the British Association at the Bradford and Glasgow meetings in 1900 and 1901.

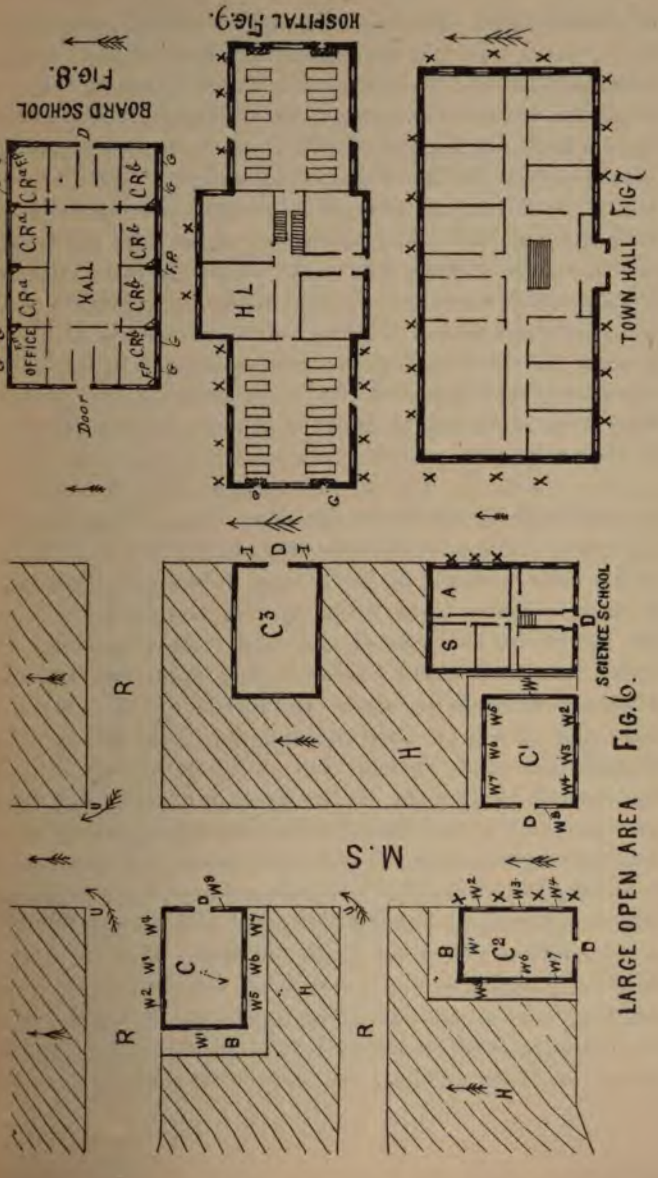
Having noticed the violent effects of the wind upon housetops, and the ventilators upon churches, etc., against which the wind impinged as it moved over a square or public park in London, and not being able to explain the reason of these

effects satisfactorily, a series of experiments were carried out upon a perpendicular cliff and promontory by the seaside. The results of such experiments showed that air as it impinges upon a perpendicular surface sticks, so to speak, and forms a cushion against the walls of houses, etc. As the air strikes a perpendicular surface with considerable velocity it flattens out, and tends to rise upward above the top of the building. A further upward movement is imparted to the air near the ground level by the forward motion of the upper stratum of air flowing over the tops of the buildings, and, during a moderate breeze, the flattening out against a perpendicular surface together with the upward twists caused by the wind currents above, give sufficient vertical movement to the air to neutralise the forward pressure of the wind, and the author frequently found he could hold a thread of silk within about two feet from the upper edge of a cliff uninfluenced by the wind, showing that no movement of air occurred at that point. When the wind exceeded 10 miles an hour, the velocity of the forward motion destroyed the protected area close to the edge of the cliff, but further inwards the onward movement was much restricted.

The results obtained from these experiments which throw the greatest light upon the reason why the wind aspirates so powerfully upon the housetops and ventilators upon buildings situated in front of open areas, and in the teeth of the prevailing winds, are the following. When the wind is what is called gusty, it has short wind waves with high crests; when the wind blows steadily, the wind waves are longer, and the crests inappreciable. When the high crest of the wind wave is approaching the top of a building it gives rise to a very powerful upward movement, hence it is that chimneys or ventilators upon buildings some distance from the front walls have great upward suction exerted upon them during the time when the crest of the wind wave is being reached, whilst the next moment as the crest passes and the hollow is ap-

proaching there is no suction at all. When the wind blows horizontally across the ventilators on a building, it meets with much friction, and its aspirating power is considerably weakened. A partly vertical movement, such as is caused by the high wind wave when the crest is approaching, escapes much of this friction, and the volume of air aspirated is greatly increased, so that when a gusty wind travels with high velocity, the air drawn out of a ventilator or chimney is vastly greater. The partial vacuum formed in a church or other building during the upward aspiration of the wind is very appreciable, hence the down draughts which result when the crest of the wave is passing are also very marked. These results explain why it is that gusty winds are so detrimental to ventilation. In addition to the vertical effects of high wind waves it is noted, from the cliff experiments, that the movement of the upper wind strata and that of the air flattened out by the impact of the wind against a perpendicular surface, hinder the forward motion of the wind. It will be seen that some twenty feet away from the front of the houses facing a park there is a *protected area,* and here the upward suction of the high wind wave will exert the greatest aspiration. Hence it is that the chimneys upon houses so situated are so smoky.

Further experiments showed that the small whirlwinds in towns were local, and due to the twisting motion given to the air by bends in a street or crescent, and by suction upon other streets leading out of those along which the wind was blowing. These small whirlwinds have a powerful upward movement, generally due to increased velocity of the wind just above the ventilating area. When wind blows along a wide street (see M. S, Fig. 6) and there are openings into other streets, R R R, at right angles to the direction of the wind, air is aspirated out of the cross streets. But the wind travelling over the tops of the houses, H H H, and over the streets situated at right angles, R R R, also aspirates air out



BOARD SCHOOL Fig. 8.

HOSPITAL Fig. 9.

TOWN HALL Fig. 7

SCIENCE SCHOOL Fig. 6.

LARGE OPEN AREA

of those streets. The wind blowing down the main street, M. S, meets with less resistance than that flowing over the housetops, and the aspiration out of the streets at right angles is greater, horizontally, at the ends adjoining the main street than it is in the vertical direction across the housetops, the consequence being that a sharp twist is given to the air drawn out of the side streets as it joins the wind blowing down the main thoroughfare. The high crests of the wind waves also give a sudden upward jerk to the air in the main street as it passes every cross road because of the larger volume of air which it meets and of the less resistance as at U U U. If a house on the corner of two streets happens to be higher than the others, the wind effects are generally very marked upon it, as shown by the fantastic chimney pots usually fixed in such a situation.

The church, C, Fig. 6, or a large public building so situated, will be subject to the same wind effects, and the aspiration of the wind will influence two sides of the building at the same time. If the door, D, is in the main street, and there is a ventilator at V on the roof and both are open, the suction at the door as the wind is blowing along the street, M. S, will cause a down draught from the ventilator when the windows are shut. If the window W^2 or W^3 is open, the air will be drawn towards the door. If W^2, W^3 and W^4 are open, then air will pass out through W^4. If the space B at the back of the church is narrow, and panes are open in the end window, the outward aspirating effect will not be great when the door is shut, but, if the space between the church and the houses is wide, then the aspirating effects of the wind blowing above W^1 will be considerable, and air will be drawn out of the building. There is a large window over the door, D, and when the door is shut, the ventilators in the window, if open, will be aspirated by the wind blowing down the main street, M. S, and much air can be drawn out of the building. As the church is higher than the

buildings adjoining, the pressure upon the windows W5, W6 and W7 will be slightly inwards.

Having obtained this information, how should the window openings be arranged to afford the best summer ventilation?—the movement of the wind, though slight, being in the direction of the arrows. W1 should be full open; W8, full open; W2, full open; W3, full open; W4, half open. After noting the temperature outside, W5 and W7 should be regulated so that the draught is not unbearable; always remembering that the movement of the air will be accelerated after the audience assembles. The same remark applies to W6, which can, however, be more open than the other two. If all the window ventilators are full open, the force of the movement of air in the direction of from W5 to W2 will throw the breath back upon the audience, and the value of W1 and W8 will be much lessened.

As another example of summer ventilation, a similar church is situated at C1; it is higher than the houses at H, so there will be upward suction over the area between the side of the church and the houses, but the wind will blow dead on with all its force against the side where the windows W2, W3 and W4 are situated. As the tops of the houses are above the ventilating panes in W1, they must not be opened too wide, and a down current should be avoided, especially when the wind is strong. If the door, D, can be opened somewhat during service it would be very helpful to ventilate the church in hot weather when a slight breeze is blowing in the direction of the arrows; and the apertures in the windows above should be open to their full capacity. The openings in W2, W3 and W4 must be regulated so as to avoid over strong air currents being produced by the wind pressure upon them. The apertures in the windows 5, 6 and 7 should act as outlets, but had better not be opened too full else the draughts from 2, 3 and 4 will be much more pronounced.

C2, Fig. 6, is a small church, but the door and window

above face the wind. Windows 5, 6 and 7 should be judiciously opened, as the air movement will be from W^6 to W^3. The church being higher than the houses, and the wind pressing against the door and window above, these may be used to let air into the building in summer. W^2, W^3 and W^4 will act powerfully as outlets and should be regulated in accordance with those on the other side of the church—W^2 and W^3 being generally more open than W^4. The wind blowing along the sides and ridge of the roof will aspirate air out of the area B, and so out of the apertures in W^1, which should be opened as wide as possible, but not sufficient to cause intermittent air currents.

The church C^2 is so situated that it can be ventilated admirably in summer with very slight wind, and C and C^1 are not difficult to work. If the wind, however, blows from the opposite direction, C becomes very like what C^1 is when the wind blows as shown by the arrows, only that the houses in front of C will break the force of the wind at W^2, W^3 and W^4. If a church is surrounded by buildings as high as itself, the problem becomes more difficult, and a large high roof ventilator will be most serviceable if the church or building is not upon a street corner, or in an open position. When wind blows over housetops, it causes suction upon all those which are not high enough to catch the impact of the wind, and, as in the case of the open tube alluded to in this chapter, the flowing wind will aspirate powerfully as it blows over the open roof ventilator. If a church or hall is surrounded by buildings higher than itself, the only chance to ventilate it in summer without mechanical aid, is by the upward suction of the wind; and it will be found most effectual not to throw windows near the top of the building too open, whilst those near the floor level should be as wide as possible and the doors open also in warm weather. The aspirating power of the wind is greater near the top of the building than at the floor level, because the air is subjected

to less friction. If a church, C^3, or a hall, as the case may be, is closed in by buildings on three sides, and the door opens on to the street with a window over it, there should be ventilators high up of good size for outlets, and these, and the door if possible, should be opened wide in hot weather.

After observing the wind aspiration upon apertures in windows, one will be prepared to learn that the suction upon other inlets and outlets by the wind will very frequently overturn the provisions made for ventilating buildings. These overturning effects may be, and often are, accelerated by the arrangement of the heating apparatus in a building. Let S A, Fig. 6, represent the first floor over a free library used as a science and art school. The front door, D, faces the prevailing winds and is kept open. The library and rooms on the ground floor are heated by hot water pipes, and there is a staircase that goes up to the science and art classrooms on the first floor. There were no folding doors to this staircase, the consequence being that much of the heated air from the ground floor was forced up to the passages on the first floor where the air pressure was so great that the Tobin's shafts, indicated by X X X, acted most powerfully as outlets.

In the church, C^2, there are Tobin shafts at the point X X X, and when the wind is blowing strongly in the direction of the arrows, and the door D shut, the Tobin shafts will be so powerfully aspirated by the wind that they will act as outlets.

Let the block T H, Fig. 7, represent a town hall situated in its own grounds. The prevailing winds blow in the direction of the arrows, and there are Tobin shafts, X X X, on the two floors, on all sides of the building. The heating is done by radiators in each room, and the foul air outlets pass into the passages near the ceiling and also through the gratings in the outer walls. The pressure of a moderately strong or strong wind blowing against the front of the building drives air up the Tobin shafts in immense volumes, and so much trouble

has been caused in cold weather that the shafts are rarely opened at all. And even when the Tobin shafts are closed, during strong winds, the down draughts through the gratings, which were intended for outlets in the front wall, render the rooms very draughty and cold in winter. Nor is this all, for the outlets into the passages at the back of the front rooms deliver huge volumes of foul air into them, and cause extra pressure upon the doors of the rooms on the other side, so that when a door is opened, the Tobin shafts and the exits for foul air through the outer walls at the back of the building pour out the foul air from the front rooms. Furthermore, the aspirating effects of the wind give rise to a decreased pressure upon the back part of the building, and the Tobin shafts frequently act as outlets, especially during gusty winds. Again, the Tobin shafts upon each end of the building are aspirated by the wind, and act as outlets during every strong gust or blow, and as inlets during every lull, so that a steady flow of air is impossible.

The block, Fig 8, roughly represents the ground floor of a Board School, showing classrooms, C Ra and C Rb, with central assembly hall. The classrooms are all heated by fires, the flues of which run up in the corners of the rooms, as marked at F. P. By the side of each flue an exit shaft for foul air extraction is carried up, and this is heated by the chimney. No provision has been made to admit fresh air, and if the windows are closed in winter, the air in the classrooms is under much tension. In other words, the pressure of the air outside is appreciably greater than that of the air inside, and the pull upon the air caused by the foul air-shaft as well as that due to the chimney, draws out or expands the air in the classrooms to a very appreciable and sensitive limit. When the wind blows powerfully in the direction of the arrow it aspirates upon the windows in the two ends of the building, as also upon those on the further side, the consequence being that much less air gets into the classrooms,

and, as the fires already strain the atmosphere to its utmost limit of tension, every severe gust of wind causes the chimneys to smoke. The side of the building against which the wind blows has extra air supplied by the wind forcing it through the window chinks, and the ventilation is fairly good; but when the wind blows from the opposite direction, the class-rooms, C Rb, are affected whilst the chimneys, being rendered too sensitive, always smoke during gusty winds.

With a view to obviate these results the windows are kept more or less open, and during very cold weather, when there is little wind, the fires draw very well; but it is difficult, indeed, to picture the condition of the nerves of the head and the eyes of the boys and girls who have to sit for many hours right under the deluge of cold air flowing over them. It is most unfortunate that such a state of things is allowed to exist. Furthermore, it is found that the aspiration of gusty winds in spring and autumn when they blow in the direction of the arrow, will draw air out of the rooms if the windows are *open* and overturn both the smoke in the chimney flue and the air in the foul air exit, the consequence being that to avoid the downpour of smoke and soot the windows must be shut, and the condition of the ventilation at such times is deplorable. If the wind blows from the opposite direction, then the classrooms on the other side are similarly affected; and if the wind blows strongly from D to D, the classrooms on both sides are more or less subjected to the evils which result from the aspiration of the wind.

The block, H L, Fig. 9, is a rough outline of a hospital building, the wards being cut short as shown by the broken lines. X X X are Tobin shafts, and from the action of those in Fig. 7 it will be seen how with one wind they will be inlets, and with an opposite wind, outlets. The heating of this first floor is by hot water pipes chiefly, but at either end there are two coils, and opposite each coil in the oute wall there is an inlet grating. The hospital is on hi

ground, and there is an open space at each end—the consequence being that very powerful suction is exercised upon the gratings at the ends of the building when a strong wind is blowing. If the hand is held near the gratings it will be found that the wind pressure upon the Tobin shafts facing the wind supplies enough air to let the wind aspirate freely through the gratings at either end, and the air heated by the coils as it passes through them is drawn out through the gratings into the open air—a result little expected, doubtless, by those who fixed the coils.

In order to condense the matter of this chapter, let it be assumed that two air inlet gratings, G, were fixed in the outer walls of each classroom in the Board School, the effects produced upon these would be similar to those upon the windows, and they would sometimes act as outlets. Where air gratings are fixed near the ground to supply fresh air to batteries of pipes, or to the flow and return under the aisles of churches and halls, it is very necessary to see that the aspiration of the wind does not prevent air entering the building, especially if the top exit space is sufficiently large to cause intermittent air currents in the structure. The church, C^3, Fig. 6, has two such inlet gratings, I I, and before provision was made to prevent wind suction upon them the volume of fresh air was much intercepted when the wind blew down the street in the direction of the arrow. In this case, as in that of the gratings at each end of the hospital, it is possible to prevent wind aspiration. The results pointed out are, however, rarely ever suspected, and, until the action of the wind is better understood, it is to be feared that little effort will be made to remedy matters.

Example after example can be given of buildings where natural ventilation, as it is sometimes called, has been adopted, and where calculations had been most carefully made of the exact outlet space necessary when so many Tobin shafts [illegible] area, were furnished, but the position of the build-

ing in the town, the probable action of the prevailing winds, and the ground swirl or suction, never received a thought. The consequence is that all these nice calculations are useless, and the system (?) of ventilation has its action reversed every time there is a strong breeze or wind blowing. The larger the apertures in the shaft inlets the more violent will be the wind effects; and before leaving the question of Tobin shafts, it is well to learn definitely that whether these or other form of inlet is provided, the area of each should be small and much subdivided.

The outlets in the form of cowls, roof ventilators, turrets, louvres, etc., are usually fixed upon the top of the roof, and, when these are so situated as to be above the surrounding buildings, the wind effects upon them need not trouble the caretaker much. As already hinted, the turrets should be so made that the wind does not aspirate strongly upon them. In the case of churches, halls, or other buildings upon a steep hill side, and covered in front up to half of their height by other structures, the outlets upon the roof or even the crevices in it, if there are no ventilators, will be under back or increased pressure when the wind blows against the face of the hill. In the case of mission halls, music halls, and small halls of assembly, these are frequently below adjoining buildings, and if one of the sides is exposed to the wind and it blows powerfully against it, the extra pressure at the top of the building hinders ventilation greatly. Where the pressure of the wind acts upon the bottom of a building as well as upon the top, the 'l-effects are not so marked—it is when the bottom of a hall protected by a wall or lower structure, and the top is ›sed to the increased pressure and violence of the wind, the effects are most pronounced; and under these cir- ınces it will be found that the roof exits will act best ›pen than when open wide.

CHAPTER III.

THE EFFECTS OF MOIST AIR UPON VENTILATION.

AMONG the many problems connected with ventilation, this is one of considerable interest. The presence of aqueous vapour in the air is not accidental, and the fact that ice itself yields it to the passing air shows that at 32° F. some vapour exists in the atmosphere. Although the quantity present in the dry air of the easterly wind, and in the January air currents, is small and much below saturation, still there is always moisture present. The affinity of air for moisture decreases as the point of saturation is being reached, and during the most humid weather that point is rarely attained. The aqueous vapour is simply steam or water-gas, and is transparent and invisible up to the point of saturation. One per cent. by volume, perhaps, is a rough average of the quantity present in the atmosphere, and, as the density of water vapour is rather more than half that of the air, the physical effects of high or low humidity do not appear to be of much consequence so far as density is concerned, as they are only equivalent to about 3° F. of temperature.

When, however, the moisture in air is regarded from the standpoint of the human body shut up in the room of a house, or in a public building, the effects are very different. Dry air is, practically, a non-conductor of heat, humid air is a good conductor, hence moist air at temperatures below 55° F. feels very cold and uncomfortable, because it robs the heat om the face and hands and from the least protected por-

tions of the body as fast as the blood conducts it to the surface, but dry air at the same temperature is pleasant and endurable. On the other hand, moist air at 60° F. is not unpleasant provided it is unmixed with the organic matters from breath, but moist air at 75° or 80° F. is very enervating and trying. The reason is that moist air not only conducts heat at this temperature, but causes the vapours evaporating from the skin to be condensed upon its surface without being quickly removed, giving rise to a hot and oppressive feeling. When the walls of a building are cold, some of the moisture from the breath of the audience condenses upon them, and upon the floating dust particles cooled by the air which comes in contact with the walls. These dust particles so moistened rouse the bacteria into rapid and astounding vitality, because the organic matters evolved in breath are excellent bacteria food, the result being that active decomposition takes place and is manifest to those who enter from the outer air by the stale and fœtid smell. Under these circumstances the body becomes heated, and, as the air inhaled cannot carry away the moisture fast enough, the feelings experienced are distressing. Nature has designed that the latent heat which the vapour of water absorbs from the skin shall be the safety valve to reduce the temperature of the body when it exceeds 99° F., and it is as necessary, therefore, that the air in our homes and public buildings should be capable of taking away excessive heat and moisture from the human body as it is that the air should supply oxygen for the combustion of the food in the lungs and blood.

De Chaumont (*Proc. Royal Society*, vol. xxv.) showed that the effects of an increase of one per cent. of humidity was equal to a rise of 4° F. in temperature, and far in excess of what might be expected, judging from the smell of the air; but the reason why this is so is not given in his paper. The results of experience show, however, as already indicated, that the increase of fœtid odour in the air is due to the increased

activity of the bacteria in confined air spaces, and that it is greatest near the point of saturation, especially when that moisture is largely the result of breath exhalation. The circulation of the air against cold surfaces causes a deposit of water mist, and this aids the bacteria greatly in attacking the organic matters in the air.

A problem of considerable interest to sanitarians has arisen with regard to the organic matters in exhaled air. Some French chemists stated that they had detected toxic poisonous properties in the liquid condensed from breath, but other observers who repeated the experiments afterwards failed to confirm their results. At the present moment there is not sufficient evidence from which to draw definite conclusions, but the subject is as serious as it is important. The fresh liquid condensed from the breath of one individual may be quite free from toxic character, but the condensed products from a moisture-laden atmosphere in which a mixed audience was assembled for a prolonged sitting of three or four hours, and where active decomposition had gone on, would not unlikely give a different result. One thing is certain, that every precaution should be taken to prevent the air in dwelling rooms and public buildings being saturated with aqueous vapour. It is likely that 70 per cent. of saturation is preferable to anything higher, at any temperature, but it will be difficult to keep it as low as this in buildings dependent upon natural ventilation when the temperature of the outside air is near that of the inside air—in other words, when the temperature of the outside air exceeds 55° F.

A point already much debated is as to whether the amount of moisture present in the air which has been heated should be increased in accordance with a rise of temperature, by evaporating water where the heating is being effected. If the outside atmosphere is below 32° F., and it has been below that temperature for some time, it is advisable to add moisture artificially, when the air is being raised to 60° or

more, and this is so whatever method of heating is adopted. When steam pipes, at a high temperature, or stoves are used for heating, it is especially needful that moisture be added to the heated air. It has never been shown satisfactorily why it is that moisture added to air which has been heated over iron plates or pipes should relieve the situation, but there is no question that it does, especially in cases where the products of respiration are known to be absent. Some compounds, carbides or what not, are formed in small quantities, and, whilst in the gaseous state, exercise a deleterious effect, but combine probably with the moisture added to the heated air, and lose their baneful properties. No such unpleasant feelings are experienced in air heated over hot water pipes which do not exceed 150° F., and, from professional experience, the author has no hesitation in saying that the addition of moisture need not be a matter of anxiety. It has been urged that moisture should be added to heated air so as to raise the moisture to 75 per cent. of saturation. There is no doubt that moisture should be added to air heated over stoves, hot iron plates and steam pipes, and it is best to make a point of doing this by providing tins to contain water which can be evaporised by the heat employed. Where hot water is used for heating, there is no necessity to do this when the temperature of the air outside exceeds 45° F. In the majority of public buildings, the same air, unfortunately, is continually circulating around the heating appliances, and the breath of the audience is reheated over and over again. So large a proportion of moisture is obtained from this source, that it is most unwise, *with the present provisions for the introduction of fresh air at the floor level*, to add more moisture, because it must not be forgotten that the larger the proportion of moisture present, the more rapidly are the matters evolved in breath acted upon by the bacteria, and the more rapidly, too, are iron carbides and unpleasant products formed by heated iron plates and strongly

heated iron surfaces. It will be time enough to deal with the addition of moisture to the air heated in churches and public buildings when the serious deficiency of fresh air introduced at the ground level has been remedied. Where, as now for the most part, air falls from the roof, and mixing with the breath of the audience, circulates through the heater or around the hot pipes, enough moisture is present. In the few instances where proper inlet provision is made, and the temperature of the air outside is below 45°, a little moisture will certainly tend to remove the feeling of dryness which the skin assumes, and the irritation of the eyes which results when dry air has been heated over very hot surfaces.

Hospital wards should only be heated by air which has passed over hot water pipes whose temperature never exceeds 170° or 180° F. If this is done I think that no moisture should be added except during very cold weather, because a dry atmosphere is more exhilarating, and one in which the germs are rendered powerless to do much mischief.

When air is moderately dry there is no fear of moisture being condensed upon the walls and cool surfaces of wards and rooms where persons are gathered who evolve sputæ, or other germs of infectious disease. The oxidation of the food products in the lungs and blood appears to proceed more readily and easily when the air, which is heated to a higher temperature by being inhaled, carries off a not considerable proportion of moisture from the lungs. From experiments carried out in the House of Commons with a view to reduce the temperature of the inlet air during the summer, it was found that although it was only lowered one or two degrees by passing over blocks of ice there was a "sensation of freshness" produced in excess of what seemed probable under the circumstances, and this was due doubtless to the condensation of some of the moisture present.

Much might be said for and against the washing and filtering of air in order to remove impurities. Some of the

leading scientists are in favour of such a proceeding. The addition of further moisture which results in winter previous to the air being heated is not of much consequence when the temperature of the air outside is below 50° F., but if it is above this, and especially in summer when the air is humid, it is not at all wise to increase the moisture present. In summer, therefore, if the washing process is done with a small quantity of water which is nearly as warm as the air, the result will be unsatisfactory and better left alone.

It is a point difficult to determine, perhaps, but a debatable question notwithstanding, whether it is advisable to remove the soot and such like antiseptic matter from the air by washing and filtering as is done in some large buildings. If a large quantity of water can be used in summer and it is cool enough to lower the temperature of the inlet air by several degrees, then by all means do it because it is unlikely that much more moisture will be taken up. In winter, unless the washing can be done thoroughly, it is better not attempted in clear weather as the antiseptic and germ killing ingredients are the first and easiest removed whilst other and more deleterious matters pass the screen. Furthermore, the value of the alkaline ingredients accompanying the tarry products in maintaining the lungs in a vigorous condition is a point which has not been duly considered.

Where such lengthy sittings occur as in the House of Commons, for instance, the air driven in should be purified from fog, but air which has been washed and filtered without having its temperature lowered is soft and enervating, lacking freshness and invigorating power.

It is impossible to heat by stoves, or to pass air over iron plates heated by a furnace without some carbonic oxide passing outwards into the air, and, where the conditions prevent this, the organic matters in the air, and especially those in breath exhalations, give rise to the compound. Various iron and other products are also generated, and these are so

nauseous that people have imagined the results are due to the want of moisture in the air. The fact is, however, that if hot water pipes are employed, and strongly heated iron surfaces are discarded, very little will be heard of the necessity to add moisture to the warmed air. In dwelling houses where there is furnace or other heating besides firegrates, the importance of adding moisture is more pronounced, especially if a person is suffering from throat or lung affections, but dwelling houses are not under consideration.

A considerable proportion of the moisture in the air of public buildings comes from the illuminants employed, especially from coal gas. About one half of the volume of coal gas consists of free hydrogen, whilst that in the combined state as marsh gas, etc., when set free, will occupy a space approximately equal to the total volume of the coal gas—in other words, there is sufficient hydrogen free and combined in coal gas, if it all was in the uncombined state, to yield a volume about one and a half times as great as the coal gas itself. When this one and a half volume combines with three-quarters of a volume of oxygen, it forms water vapour, and the $2\frac{1}{4}$ volumes contract in bulk until they occupy $1\frac{1}{2}$ volume, *i.e.*, the same space as the free hydrogen occupied. Every three jets of gas burning for one hour, and each consuming five cubic feet, will yield twice as much vapour to a thousand feet of air as was probably originally contained in it, and so may be the means of saturating the thousand cubic feet even at the increased temperature. It is this moisture which adds to the oppressive, close and clammy feelings experienced after the gas has been lit some time, and the carbon products of combustion are even less to blame.

In churches, chapels, public halls and theatres, where the gas jets are distributed over the interior of the buildings, and the heating and ventilation have received so little atten-

tion that no warm fresh air has been admitted near the floor level, the same conditions occur, and the products of gas combustion, and of breath, circulate and remix until coming in contact with the walls, windows and other cold surfaces, some of the moisture is precipitated in the form of very fine mist, and the decomposition of the organic matters exhaled is so rapid, and the activity and multiplication of the bacteria so stimulated, that a person coming in from the fresh air gets a sufficiently strong experience of what foul and fœtid air is like.

It may be urged that owing to the increased temperature of the confined atmosphere the capacity of the air to absorb moisture would also be increased considerably; and, as this is true, it will be well to inquire and define the extent. The temperature of the air in a public hall just before the gas was lit and the audience assembled was 59° F., and it had increased to 72° F. one hour afterwards. The tension of aqueous vapour, or the capacity of the air to absorb aqueous vapour by being raised in temperature from 59° to 72° F. would only be increased by one-third, whilst the saturated breath at about 97° F., and the vapour from the gas consumed, would saturate a very much larger volume at the increased temperature of 72° F. For example, the hall holds 1,000 adults, who exhale one-twelfth of a pound of moisture per head per hour at nearly 97° F., eighty-three and one-third pounds of water are therefore evolved from the skin and in the breath by 1,000 persons, and this water will saturate 100,000 cubic feet of air at 72° F., calculating that the air as it entered the building contained moisture equivalent to half saturation at that temperature (72° F.).

One thousand cubic feet of gas are consumed every hour, and the moisture so formed would saturate nearly 100,000 cubic feet of air, so that about 200,000 cubic feet of air will be fully saturated from all sources. One thousand cubic feet of average coal-gas require 6,000 cubic feet of air

to yield enough oxygen for combustion, but as only a portion of the oxygen would be used by the flame, probably 30,000 cubic feet of air took part in the combustion of the gas, and this, together with 20,000 cubic feet of air exhaled from the lungs, make 50,000 cubic feet, which saturate about 200,000 cubic feet, or approximately four times the volume.

These figures are not exact because the facts relating to breath and to coal-gas cannot be determined with certainty, but they are not overstated. The quantity of water exhaled by the skin and in the breath is said to vary from 25 to 40 ounces in the twenty-four hours, and there is much difference between the composition of gas made from cannel coal and that made from the ordinary bituminous varieties.

The figures show very plainly how inadvisable it is to use naked coal-gas flames to heat churches and public buildings in cold weather, as the moisture condenses on the walls and cooler surfaces, and when exhaled air is present, organic products are condensed also, and give a stale, musty, unhealthy odour, which hangs about for a long time. Committee rooms, mission halls, school and class rooms are frequently heated in this manner, and, after a far too numerous audience has assembled, every inlet for fresh air is carefully closed, and the stinking organic products re-inhaled into the lungs must seriously affect weak constitutions, and, strange as the fact is, it is the weaker portion of the community who are the most devoted mission and school workers.

When air is supersaturated with moisture it becomes heavier and impedes ventilation most seriously, as condensation occurs in the cracks and interstices through which the air finds exit, and stagnation of the atmosphere results. This is frequently the state of things in unventilated buildings when the temperature of the outside air is low, and its condition damp and foggy.

Nature has acted wisely, however, in the matter of moisture

in the air. The fact that water vapour is so much lighter than air, tends towards ventilation, and as the vapour in breath is exhaled generally at about 97° F., the high temperature also assists in causing the expired air to rise upwards. The nearer the temperature of the outer atmosphere rises to that of the body, the more difficult it is to cause much upward movement of the air in a building during the summer time, and, were it not for the fact that moisture is lighter than air, and that the moisture in breath is evolved at a high temperature, there would be no ventilating force at hand to cause the foul air to be removed. The ventilating power due to breath, although appreciable and valuable in the summer, is, notwithstanding, small in amount, and every means should be used to cause the circulation of air within a building by taking advantage of wind currents and open windows. This matter, however, will be further mentioned in the next chapter.

CHAPTER IV.

AIR, AIR INLETS AND OUTLETS.

IN this treatise the composition of air, the nature of the impurities common to the atmosphere, and theoretical considerations of the sciences bearing upon ventilation, are omitted, because such information can be got without difficulty from various sources. Neither ventilating engineers nor the caretakers of present buildings need worry much over the impurities in the atmosphere outside the building, but direct their energies almost entirely to keeping that inside the structure in a breathable condition.

No pains should be spared, however, to see that the air which feeds a building is not contaminated by sewer gas or such like impurities, and, once this has been ascertained satisfactorily, the only thing which need concern the caretakers of present buildings is to see that all the air possible shall be introduced, even to the point of causing dissatisfaction to some who frequent the building. With churches and public halls, what the caretaker should ascertain is not how much air is required, theoretically, to keep the percentage of carbonic acid below a certain point, but how much it is possible, under the existing arrangements, to introduce without causing unpleasant and injurious draughts. He need not trouble whether Parkes was right that 3,000 cubic feet per head per hour was the proper quantity to keep the atmosphere breathable, or whether Carnelly, Haldane, and Anderson were nearer the mark with 1,000 cubic feet per head, because there

will be little fear that he will be able to get a volume anything approaching the latter into his building. It is only reasonable to assume that most caretakers have little idea how many cubic feet per head per hour do get into churches or halls, but, from experience, the author is confident that 300 cubic feet per head is much nearer the mark than even Haldane's computation. When the weather is foggy, and the air is moist and damp, the 300 cubic feet per head per hour is a high average for churches and halls. During the spring and autumn when it is fine, and the air outside is from 50° to 55° F., the average may be 300 cubic feet, and during cold weather 400 cubic feet per head. In some mission halls, 150 cubic feet per head would more nearly represent the actual quantity when the worst conditions of weather prevail. During the first half hour of assembly the proportion of impurities is not so noticeable—it is during the last half hour of the sitting that the greatest discomfort is felt. The building is filled with nearly pure atmosphere before the audience gathers, and some time elapses before the body of air is much contaminated.

It is most desirable that the supply of air to a building should not be less than 750 cubic feet per head per hour, *but this quantity cannot be obtained with comfort to the sitters unless provision, and careful provision too, has been made for warming the air introduced at the floor level before it reaches the audience.* Seven hundred and fifty cubic feet per head of cold air introduced into a building, whether large or small, would mean intolerable draughts; and during very cold weather, 500 cubic feet of unwarmed air would be unpleasant and productive of chills, colds and neuralgia to those seated near the doors, windows, or cold walls, whilst their feet would be rendered unbearably cold. Some may think that the volume of air actually supplied, namely, 300 cubic feet per head per hour, appears small, but it is well over, rather than under stated, and, whilst calling attention to this, it is neces-

sary to point out that the air supply mentioned has to reduce the impurity caused by the burning of illuminants, in addition to that evolved in breath. In many churches and halls the electric light has been installed, but it may be concluded, generally, that the ventilation has not been improved by the change, because the extra heat evolved by the gas and the moisture formed gave rise to a greater ventilating pressure, and caused more air to circulate than was the case after the electric light was adopted. It was inferred by the author many years ago that the moisture and organic matters in breath were the greatest impurities in the air and those which gave rise to the foul smell. This deduction was arrived at after experimenting with gas in large quantity, and after many hours burning in a building, the smell and effects were not very marked. The adoption of the electric light in churches and halls has confirmed these experiences, and the reason why the atmosphere is more stale and foul since the alteration is because less air circulates, and it is nearly, if not quite, saturated with vapour from breath.

The question arises, naturally, in reference to the churches, halls and public buildings which will be erected in future, whether it is advisable to make provision for heating and distributing as much as 3,000 cubic feet per head per hour. The answer to this question depends much upon the kind of heating provided, and the manner in which it is proposed to introduce fresh air into the building. Still it is not necessary, nor will it be practicable, to aim at more than half that quantity, whilst if 750 cubic feet be supplied and the audience does not remain more than one hour and a half in the building there will be little complaint made of impure or bad air. In buildings where a large number sit for many hours at a stretch, a larger volume of air should be provided if possible.

Dr. Parkes concluded that the gaseous products of combustion in a building were evenly distributed, and if there

were two parts per 1,000 of carbonic acid in the air near the floor of a hall, there would be the same quantity at the top. This result was inferred from the experiments of Lassaigne, Pettenkofer and Roscoe, but as it depends upon the quantity of aqueous vapour present in the upper portion of the air in a building as well as upon a number of physical conditions, it is wrong to assume that the carbonic acid is always equally distributed. If the upper air is saturated with moisture the carbonic acid is held in suspension in a semi-dissolved condition, but if the air is moderately dry, the carbonic acid which is at first rapidly carried upwards by the heated moist atmosphere afterwards descends quickly so that its diffusion is greatly accelerated. If the building is large the air near the floor is the purest, that under the galleries, if there are any, is the most impure, the air near the walls above the galleries has the next largest impurity, whilst in all cases, and notably in those having too much top outlet, the atmosphere in the centre of the building will be the purest. Even where the hot air furnace is used as the heating medium, if there are galleries, the air is not *evenly* mixed, although in consequence of the circulatory movement given to the air by this method of heating, it is approximately the case. Without galleries the admixture is much more certain. Where hot water pipes, steam pipes, radiators, or even coils of pipes are fixed above the floor of the building the movements of air are chiefly vertical, because of the more even distribution of the heating surface, and, while much preferable to the air furnace method, is equally as effective as pipes sunk below the floor, *unless provision is made for fresh air to come from the outside and to be warmed before it leaves the pipes.* Hot water or steam pipes fixed either below or above the floor cause vertical movements in the air, chiefly, and the vapour of the breath and that due to the burning of illuminants also greatly assists in causing an upward movement. The amount of carbonic acid may be considerable, even at a few feet from the floor

level, and in excess, comparatively, of the moisture present at that point, but at higher levels, the proportion of moisture due to respiration is more than equivalent to the carbonic acid. In other words, whilst the carbonic acid in the air of a building tends to diffuse rapidly because of its weight, the moisture from breath and from the illuminants does not mix at the same rate, the consequence being that the latter largely predominates where the air is most stagnant—under the galleries for instance—and in the upper portion of the building. It is well known that the temperature of a building occupied by a large audience is much higher in the galleries than in the centre of the floor, but once let the air become saturated with moisture, it is possible to find these conditions reversed if the chief supply of air comes from above in the shape of intermittent currents. Where little provision is made to introduce warm air at the floor level, and the building is heated inside, attempts to bring sufficient air from the top to keep the atmosphere breathable will be bound to culminate in intermittent currents, and up and down movements of the air. Unless the building is very high and of much larger dimensions than the seats require, so that there is a wide space next to the walls, unseated, it is fatal to comfort and good ventilation to heat the air in a building simply by radiators without any fresh warmed air being sent in.

Air Inlets and Outlets.—In books on ventilation it is usual to calculate what size the inlets and outlets should be, and how many square inches are required for each person. The volume of air advocated for each person according to Parkes is 3,000 cubic feet per hour, and assuming that 5 feet per second is the maximum velocity allowed for the incoming air, 30 square inches is the inlet space necessary for each person. An authority on ventilation, who is usually careful and accurate, says that if the inlet air is to be introduced through the floor in a building, the area of the openings for each

person must be at least 100 square inches. The idea is, doubtless, to reduce the *velocity* of the current of cold air coming in to about 1½ feet per second, but this will not reduce the frigidity; and just imagine 300,000 cubic feet of air per hour at 10° below freezing point flowing over the floor in a room holding only 100 persons. The idea is absurd in the extreme, and it is sheer nonsense to advocate the introduction of such a volume of cold air into a building seated up to the walls and occupied by an audience.

The Education Department advise, for public schools, that 2½ inches be the minimum air inlet space for each scholar. This is a sensible allowance, and it is not advocated that the air shall be unwarmed either. In justice to the profession, it is necessary to add that in my experience no architect has ever attempted to provide 30 inches of inlet space for each person; and it is best, perhaps, to calculate what this allowance would mean if put into practice. A church is 100 feet long and seats 600 persons. The windows are nearly air-tight, and the doors close fitting, so that less than 60,000 cubic feet per hour get through them. This allowance is a high average for churches whose windows are for the most part air-tight. The remaining inlet air for the church is to be provided by Tobin shafts, which to simplify calculation are 12 inches by 5, or 60 square inches in area. To afford the inlet space mentioned above, it will be necessary that the Tobin shafts should touch each other throughout the whole length of both sides of the building—*i.e.*, 200 feet—and that there should be, in addition, 80 feet run of Tobin shafts at the ends.

It is generally assumed either that the area of the outlets ought to be greater than that of the inlets, to allow for the friction of the out-going air, or they are advocated to be of similar area, and not to exceed 12 inches square each opening. Taking the example already given of a building 100 feet long, it would not be possible to get the 12 inch

ventilators on the apex of the roof, because they would exceed 100 feet in length when they touched each other. A ventilating engineer would not recommend more than three ventilators for such a building, hence it will be seen how absurd and impracticable the above figures are. Let any one try to imagine a continuous Tobin shaft 100 feet long and 5 inches wide belching forth cold air at 32° into the side of a building, and another shaft of similar length doing the same thing on the other side. And this is the practical ventilation of the twentieth century.

If air is to be introduced into a building in its raw, cold condition, it should fall, if possible, through 30 feet of warm air, and not more than 5 square inches per person should be attempted; and even the 5 square inches ought to be greatly subdivided. It will be seen that the fixing of the cold air inlets as high as possible is done so that the cold air shall be warmed before it gets to the audience, and all modern writers on ventilation suggest that air inlets should be raised higher than formerly. But such attempts only deal with the fringe of the matter. If the cold air is warmed in its fall, it implies that the pure air has been largely mixed with the hot products of the breath of the audience, and really rendered so vitiated that it is not fit to be inhaled.

It has been shown already that inlets of the Tobin type are most unsuited to be fixed to buildings where seats abut the outer walls, and in nine cases out of ten they are kept closed, being unfit for winter use, and useless for summer, as window openings are more effective. Where cotton wool is used in such shafts, the volume of air going in is reduced to one-twentieth perhaps, and the inconvenience and draughts are not so bad; but during very cold weather persons sitting near cannot endure them open; and felt and such like material is used to prevent air leaking around the valve when it is closed. Air inlets of the Tobin type or any large cold inlets are condemned for other reasons than the intoler-

able floods of cold air which they admit when the temperature is low outside. It is shown in Chapter II. that the wind effects upon Tobin shafts and similar inlets for cold air are very considerable. If the wind blows at right angles to the opening in the outer wall, the extra pressure forces a deluge of cold air inwards. If the wind aspirates on either side of the building, or causes reduced pressure at the back, Tobin shafts may act as outlets at every gust of wind, and as inlets during every lull in the storm.

The wind effects upon outlet ventilators are equally erratic, and generally at cross purposes with the effects upon the inlets. If the wind blows at right angles to the ridge of the roof, an upward twist caused by the upper wind currents, accelerated by the slant of the roof, will cause a powerful upward suction upon the ventilators above the ridge. On the other hand, if the roof of the church forms a line running east and west, and the wind blows from either quarter, the effect upon ventilators above the roof will be normal; whilst upon the full length of the building on both sides the Tobin inlets would be under a powerful aspirating influence, unless some careful provision was made to overcome the aspirating action—a provision which it is hardly necessary to say has not been made because the action of the wind was not studied. If the ventilators are fixed in the side of the roof itself, and flush with the tiles, they will be aspirated powerfully on both sides when an east or west wind is blowing. If the wind blows from the north, from the south, or south-west, the increased pressure of air upon the one side, and the reduced pressure on the other side of the roof, will tend to cause an up current in one half of the ventilator and a down current in the other half, especially if the building is inclined to be top heavy in outlet space. Ventilators in the sides of the roof do not admit of the full ventilating power of the building being used, and are not to be recommended owing to the very variable action of the wind at the outlets.

The position of a church or building, moreover, may be such, and often is, that a strong wind causes a considerably reduced pressure upon the whole building owing to its sheltered position, and the consequence will be that all the inlets and outlets will be aspirated with a force varying according to the gusty nature of the wind. It will not be difficult to realise that if there is a large inlet, or if the outlets are of greater area in the aggregate than the inlets, as they usually are where large outlet tubes are employed, the atmosphere in a building may be turned topsy turvey at every severe gust of wind, especially if its duration is for one minute or more. It is well to remember that a building containing from six to ten thousand cubic feet of air in one hall, offers a very large body of elastic matter to be expanded by the aspirating influence of the wind. If a string of elastic one foot long is pulled, it soon stretches to its utmost limit; but if that string is six thousand feet long what a distance it will stretch before the limit is reached! The thousands of cubic feet of air in a large building represent such a long thread of elastic, and the aspirating effects of a gust of wind, the drawing out or expanding the air in a building, like a long elastic thread is elongated by pulling at one end. But immediately the gust of wind ceases, and a lull occurs, the air contracts and snaps back like an elastic thread which has been strained and suddenly released. It is very difficult, therefore, to ventilate buildings when both their inlets and outlets are aspirated and subjected to reduced pressure at the same time, and at every gust of wind.

On the other hand, the reader will see it is possible for some buildings to be sheltered at the top, and subjected to considerable pressure at the bottom whenever the prevailing winds blow; and that under these conditions the ventilation of a building may be much assisted.

It is very evident, however, that the questions of air inlets and outlets are much more complex than a simple calculation

of figures, and it is not surprising that the ventilation of large buildings is generally in a most unsatisfactory condition.

The question whether the foul air should be drawn from the top of the building or near the floor level is still in dispute. During the past century, especially about its latter half, it had become recognised that owing to the heat of the breath and the presence of so much water vapour in it, it must rise upward quickly by virtue of its lesser density. The heat of the bodies of the audience is also a factor to be reckoned with, and some have thought that this alone was sufficient to cause an upward movement equal to one inch per second. When the temperature is very low within the building, say at 53°, and that of the air outside is 30°, the velocity of the air caused by the warmth of the bodies of a closely packed audience is nearer two inches per second. In the face of the fact that lighting by gas gives rise to much heat, and that even the electric light emits appreciable warmth, it ought to be self-evident to all that the only way to get rid of impurities and a foul atmosphere, is to drive it out at the *highest point* of a building. The larger number, perhaps, of ventilating engineers concluded that this was the only alternative, but it was thought by not a few that by the aid of powerful fans air could be impelled downward, and so prevent dust and other impurities being drawn in at the floor level, as when upward ventilation is employed. The main contention is, however, that the impurities in the atmosphere of a building are found in great quantity at the floor level, and this is quite erroneous. It has been proved again and again that the most vitiated part of a room, a church or a public hall is near the ceiling, if there is one, but in all cases in the upper part of the building, unless the area of the outlets is greater than that of the inlets near the ground level; in which case the upper layer of the atmosphere will be diluted by cold air which forms down draughts and intermittent air currents. It has been found to be absolutely im-

possible to remove the heated products downward, and where there are galleries, it could not be done partially without seriously inconveniencing those in the body of the hall or church. During the past century downward ventilation has had a fair trial, for among other places it was tried in the French Chamber of Deputies, under circumstances where monetary considerations did not handicap the system. Wherever it has been tried on a large scale, that failure which common sense, with a knowledge of the physical behaviour of gases, predicts, has invariably been experienced. And yet, even during the opening of the present century, in the pages of the leading engineering and sanitary journals, down-

Fig 10

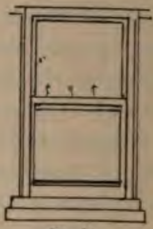


Fig 11

ward ventilation has been advocated, hence it is not so surprising that the science has made such little progress in the past.

As the problem of admitting air into a building is surrounded with many difficulties it can only be dealt with by considering all the present arrangements employed. During recent years the upper portions of the windows of some churches, halls and other buildings have been fitted with framed glass panels which when open and shut form a V, Fig. 10. It was thought that this arrangement would shoot the air some distance into the building, but they are generally closed in cold weather, and are open to the objection already mentioned that if the air descends to the audience it is so

vitiated as to be unfit for inspiration. For school classrooms and lesser halls, the windows are made to open, and various well-known devices for blocking the sills and for shielding the lower sash when it is raised two or three inches, have been advocated and tried, Fig. 11. These are useful when the temperature of the outer air is 55° or more, but they are only a makeshift at the best in cold weather.

It is desirable to consider the condition of some of the Board Schools in slight detail, because in reference to the ventilation of these the architect is advised by the Education Department. As already noted, 2½ inches of inlet air-space is the minimum advocated for each scholar, in addition to what leaks in around windows and doors. As the windows open generally, or a portion of them, a considerable volume of air is admitted in this way. But where fires are used in the classrooms, the cold air falls over the coldest material, and down beside the coldest and outer walls, and the 2½ inches of inlet air-space are generally furnished through the outer walls also. If the fire is in the centre of the interior wall—the best place for the chimney to draw—then the children near the windows are much too cold, and those near the fire too warm. But the worst feature is, that nearly all the inlet air, instead of rising up to the level of the children's heads, flows along the floor of the room during cold weather, for the most part in a stream not more than 18 inches deep above the ground level, giving the scholars cold feet and legs, but little fresh air to breathe. It is a fact, however, the Education Department recommends that each classroom shall have one or more outlet shafts, and that these be carried up by the side of the chimney flue from the fire heating the room. By this arrangement the walls of the outlets will be warmed and so create a stronger current. Under the circumstances it may be concluded that the inlet air must ascend and be inspired by the children because the outlets begin above their heads. Unfortunately, this argu-

ment, so convincing in theory, does not hold good in practice, except, perhaps, for a few weeks in the aggregate during the year. When the temperature of the air outside is below 50° it is found that if enough air is let into the classroom to feed the fire and still allow the foul air to pass through the outlets it is impossible to keep the room sufficiently warm; and, as a bright fire is maintained then, the smoke and air are hotter in the chimney than the foul products in the air outlets, and little or no air ascends the latter. Furthermore, for want of proper arrangements at the mouth of the outlets, and sufficient velocity in the foul air shafts, the very moment they cease to give an up current, cold air from above descends the outlet shafts until it gets warmed and expanded, when it rises again. The cold air may fall 10 or even 20 feet, according to the height of the outlet flue, become warmed, and rise upwards, so forming intermittent air currents which further tend to make outlet action impossible. It may be concluded as a general axiom that where fires are used for heating, and no other provision made for warming the inlet air, the fires cannot keep up the temperature in cold weather when there is enough air admitted to furnish some for the foul air outlets. When the air is above 50° outside, it may be assumed that the windows can be opened so as to increase the pressure upon the air in the classroom, but if this is done in windy weather, the powerful action of the outlets during every lull in the blowing of the wind so pulls upon the air in the classroom while the blast of the next gust of wind lasts, that if the wind aspirates upon the openings in the windows the fire is caused to smoke. By arranging valves in the fireplace, just above the fire, so as to reduce largely the volume of air going up the chimney, it is possible to make the foul air outlets more effective, and this ought to be done.

Where children are educated by the million in public schools, no excuse exists for such discomfort, rheumatism,

neuralgia, cold in the eyes, and other ills from which the children too frequently suffer; and a better state of things ought to prevail. Indeed the Education Department should be in a position to demand that every school, newly erected, shall be heated by hot water pipes only, kept at a temperature of about 150° F.; that the outer walls shall be warmed, and all inlet air of a temperature below 55° F. before it gets into the building; that proper outlets be provided, and the currents in them assisted either by heat or by fan action. In this way 500 cubic feet of air per hour per scholar can be provided.

For hospitals and barrack dormitories, where there is sufficient margin near the outer walls, cold air inlets may be used judiciously; and, as the beds are not near the floor level, it is not difficult to do this without causing draughts. Owing, however, to the vagaries of the wind it is most advisable to subdivide the surface of the inlets greatly in all instances, because it will be found that inlets of a superficial area of only 16 square inches have a peculiar knack of sending a stream of cold air a long distance when the outlets are aspirated by the wind.

As the warming of the inlet air is frequently attempted, it will be well to consider the matter at this stage. Many churches and buildings are heated by hot water pipes sunk below the floor level in the aisles; and in some cases hot water pipes are carried along the walls above the floor level as well. Referring first to hot water pipes fixed below the floors, it frequently happens that openings every ten feet or more perhaps of the length of the building convey fresh air through gratings in the outer walls to the trough in which the hot water pipes are laid. Owing to the difficulties which the distribution—or want of distribution—of the inlet air along the pipes between the air inlet channels entail, the cold air usually rushes up just above the point where the fresh air channel joins the hot water pipes, and, for the most part,

unheated. When the weather is very cold the result is disastrous, as the frigid air rushing up flows right and left giving rise to intolerably unpleasant air currents. In some cases perforated zinc has been used to prevent the air coming up in a deluge at one place, but owing to the difficulty of keeping the sheets of metal flat, and preventing the nap from the cushions and other woollen matter filling up the holes, the full benefit of this most desirable method of introducing fresh warm air has rarely if ever been attained. Where a fair attempt has been made to properly distribute the incoming air along the whole length of the pipes, in nearly all instances there is too much top exit space in the roof to enable the air inlets to work satisfactorily. It has been shown already, that apart from the wind effects upon inlets and outlets, too much outlet space in comparison to the area of the inlets always results in the formation of intermittent air currents in churches and public buildings during cold weather. When there is an up current moving, the whole ventilating power of the building is brought into play, the result being that much pressure from the outside causes great volumes to enter through the channels feeding the hot water pipes below the floor. Even with fair distribution, the sudden pressure forces incredibly large volumes of air at the critical points where the fresh air inlets join the trough in which the hot water pipes are laid. If the temperature of the outer air is at 32° F. or lower, human nature cannot bear the inrush of frigid air, and the caretaker after one or two such experiences is so afraid to have a repetition that he closes the gratings in the outer walls which feed the fresh air channels, and so a most useful arrangement is rendered inoperative.

During the latter portion of the nineteenth century, the authorities of most Nonconformist places of worship adopted the hot air furnace for heating—the cold air in the building descending one grating, then passing over heated iron

plates, and finally re-entering the building by another grating. In this method of heating, provision was made for the introduction of fresh air, but the instances in the author's experience in which a large volume of fresh air was so heated, rose vertically to the upper part of the building, for the most part, and proved of very little use. When a building is to be heated by the hot air furnace, the advantage of shutting the top air outlets is manifest, but experience shows that very frequently the leakage around the valves of the ventilators and through the crevices in the roof is so considerable that, unless the heating during cold weather is commenced on the Saturday, the building cannot be warmed for the Sunday services. The caretaker soon realises that it is no use to send fresh air warmed into the building, because this simply ascends vertically at the end where the hot air grating is fixed, being forced upward by the cold air which descends from the roof at the other end. It is more than he can do to warm the air *inside* the building, and all his efforts are directed to closing every inlet and outlet so that the circulation of the air inside shall warm the walls. The caretakers are afraid to experiment, and if they do and fail, the complaints of the pew owners soon check their ardour, the result being that the fresh air provision is very rarely used. Nor are the caretakers to blame, as the ventilation and heating of the building should be placed beyond the experimental stage before it is given into their charge. The hot air furnace is not to be recommended, because if the air inlets are opened, and fresh warm air admitted in large volumes, it will be found that in nearly every instance cold air will fall from the roof at the other end driving the heated air out in a perpendicular current. Again, the action of wind currents either upon the ground level where the fresh air inlet is situated, or upon the outlets in the roof of the building, will cause intermittent air currents inside, and greatly interfere with the ventilation. The author watched

these movements many Sundays in a place of worship where much fresh air passed through a heater, and the results were most unsatisfactory. In the case referred to, the means for shutting off the fresh air would not act, and the caretaker not knowing what was wrong, did his best under the circumstances.

Arrangements have been made in many buildings to heat fresh air by passing it through coils or over heated pipes fixed above the floor. If there is a wide aisle or space between the outer walls and the seats, it is possible to have coils, radiators, or simply rows of hot water pipes so arranged that fresh air can be warmed by them before it gets into the building. The colder the air outside the denser it is, and tends to flow in from the air inlets at the bottom of the coils, being only partially and imperfectly warmed. This behaviour of the inlet air is accelerated by the portion which is superheated, for this ascends quickly and gives rise to an upward movement which is fed very largely by the inside air. In many instances, much the greater portion of the inlet air flows in near the floor level in an unwarmed condition to supply the place of what has moved upward; and if air is more evenly heated before it gets into the structure, it ascends and rarely gets into the lungs of the audience.

Space will not permit, nor would it serve a useful purpose, to detail the attempts made to heat inlet air by the various hot water and steam coils and radiators used, but until recently no great effort was made to devise a satisfactory way of heating fresh air by coils fixed to the walls of the building. Radiators are now made which enable air to be heated by passing through tubes inside the radiator, and much more attention is given to inlets in association with radiators generally. It is not the radiators, however, which are so much at fault as the introduction of warm air in the wrong portion of the building. It has been foreshadowed already how the heated air ascends, and, although a cold current

from the walls and windows flows downward, still a powerful current of hot air ascends a foot or two away from the walls, and in the portion of the building where cool air would be more beneficial because it would flow towards the centre and seated portion of the structure. The larger and higher the building the more diffusion takes place, and the air currents are less perceptible generally, but to bring fresh air through radiators standing against the outer walls must always tend to create down draughts in the centre, especially if the roof has many interstices, and the outlet space renders the building top heavy.

Where fresh air inlets exist, the gratings in the outer walls should be protected from being aspirated by the wind, and they ought to be capable of being removed easily, so that the ducts might be cleansed from dust. In those structures where coils are fixed against the outer walls, attention should be given to the condition of the outlet spaces in the roof so as to make sure that the warmed air is caused to circulate as much as possible in the centre of the building.

The internal structure of large buildings is so variable—some having galleries, some side transepts with separate roofs, some being low, some very high, some being ceiled, some being open almost to the apex of the roof—that it is impossible to lay down any rule whether much cold air can be admitted without causing draughts. Each structure will have to be taken upon its merits or demerits, and the best provision for inlet air, either cold or heated, must be made according to circumstances.

There is no doubt whatever that the only satisfactory method of ventilating new buildings is to introduce warmed air through a large number of small openings in or just above the floor of the structure, and then make sure by the careful laying of felt upon the roof, and rendering the joints of the felt air-tight, that the outlet spaces, in the aggregate, are not of too great an area. The building should be high,

and unceiled to near the apex of the roof, then the ventilating power of the structure will be sufficient to give fair results even during the warmer weather of spring and autumn. Now that the electric current is provided in most towns, it will be neither difficult nor expensive to fix a fan which may be used to assist the ventilation of churches and halls when the temperature of the air outside approaches that of the air inside—that is from 53° to 63° F.

CHAPTER V.

CHURCHES AND PUBLIC BUILDINGS AS THEY ARE.

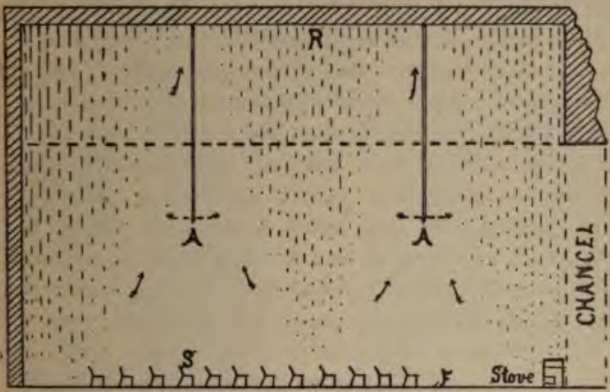
As the ventilation of churches and public buildings must necessarily depend upon their form and architecture, it will tend to make a very difficult subject more clear if a number of illustrations are given showing the types of buildings erected and what is wrong with the ventilation and heating.

Reference will be made chiefly to buildings erected some years back, and attention will be given at first to those which have no induced ventilation other than the heated air by which they are warmed, the gas or other illuminant by which they are lit, and the heat evolved in the breath and from the bodies of the audience. With a view to show the movements of the air in public buildings, a rough outline of each type of structure is given, and in all cases the cold currents of air are shown by dark shading, and the direction of the currents, whether circular or otherwise, by the manner in which the shading is executed. The direction of the warm air currents is indicated by arrows. In some cases the buildings have galleries which are not shown in the drawings, and, when that is the case, they are omitted for simplicity's sake.

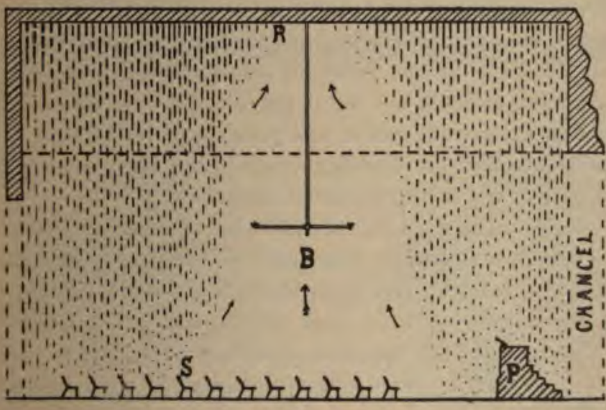
Fig. 12 and Fig. 13 indicate the movements of air in numerous churches, chapels, and halls which have no fixed ventilators on the roof and where the foul air escapes through cracks and interstices between the rafters and ceiling, or in the match-boarding as the case may be. This class of build-

ing is not ceiled, but is open practically to the apex of the roof, and boarded or plastered between the rafters. Fig. 12 represents a church where a certain volume of air leaked from the roof, R, but not enough to give rise to very perceptible down draughts even when the temperature of the air outside was at 35° F., whilst the tension of the air in the building was so relieved by the leakage falling from the roof that the air which got in around the doors and windows did not give rise to unreasonable draughts or discomfort. The dotted line shows the level of the wall plate upon which the roof rests, and the height from the floor, F, to the roof, R, is 38 feet. When the temperature of the air outside was at 45° F., there was a strong pull upon the air in the building, and much air was drawn around the doors and windows as well as from the fresh air supply to the stoves, of which there were two. When the air outside was at 55° F. the ventilation of the building was at its worst point, and if the openings in the tops of the windows were kept shut it was very bad after an audience had been seated for an hour. The large stoves heated the air inside the building, but the volume of fresh air admitted through them was very inadequate. The building was lit by two ring burners. The church wanted much more warmed fresh air, and two roof ventilators which could be closed completely by suitable valves when the temperature of the air outside was 40° F. or less.

Fig. 13 is a section through the apex of the roof of a church, and the dotted line shows the level of the wall plate. S represents the seats, and P the pulpit. From the depth of the shading it will be seen that more air fell from the crevices in the roof when the temperature outside was at 35° F. than was the case in Fig. 12, and the movements of the air inside and the down draughts were decidedly unpleasant. It was quite possible to notice how the air circulated so that the coldest portion might be heated by passing down the gratings under which hot air pipes were fixed. There were



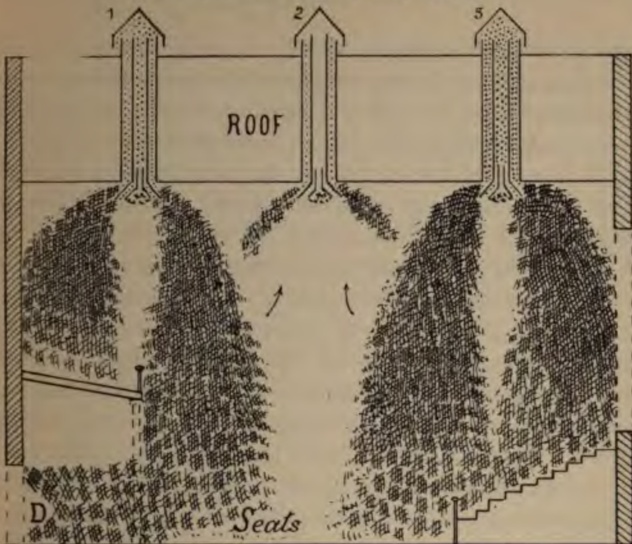
SECTION OF A CHURCH, FIG. 12



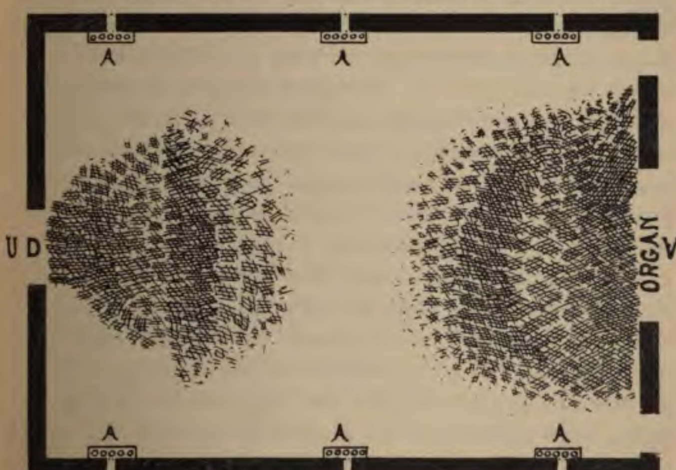
SECTION OF A CHURCH, FIG. 13

three fresh air inlets on each side of the church connected to the lines of pipes, but owing to the intermittent air currents in the building they were kept closed. The gratings above the pipes in the church were excellent, and nearly three feet wide, but more than two feet of this was covered with close Kidderminster carpet which prevented the circulation of the air through the grating, and reduced the heating effects of the pipes by at least one-half their power. Furthermore, on removing this carpet and raising one portion of the grating, the hot water pipes were found to be covered with a coating of fine woollen down, nearly half an inch thick, which further reduced the heating value of the pipes. When the temperature of the air outside was above 50° F. there was no appreciable down draught, and, for the most part, the air leaked from the roof without giving rise to perceptible movements, whilst the ventilation seemed to be fairly good. The church was lit by a large central gaselier at B. The ventilation of this church was top heavy, that is, the outlet spaces in the roof were too many, and the cracks between the match-boarding required to be partly closed. Then the air from the fresh air inlets wanted more careful distribution, and the hot water pipes to be kept clean. The carpet was removed, and it was possible to render the ventilation good, and the building comfortable for the audience, without making much structural alteration.

Fig. 14 was a large public hall seating 1,500 persons. It was ceiled some 40 feet from the level of the ground floor, and was at least 60 feet high to the top of the roof. The building was lit by three large sun-burners whose exit tubes were surrounded by spacious cylinders several feet in diameter. When the tubes and cylinders were open in moderately cool weather, the area of the outlet space was much in excess of that of the inlets. At a concert the author attended, and watched the air currents, the principal tenor came to the platform in his overcoat with the collar carefully



VERTICAL SECTION THRO. UV, FIG. 14



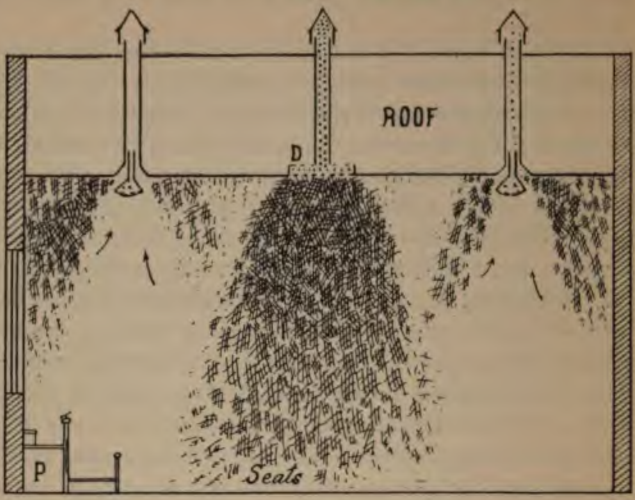
GROUND PLAN, FIG. 14

raised around his neck to shield it from the draught. The night was very cold, and owing to the down draughts the movements of the air were sufficient to cause an anemometer to revolve continually while lying on the seats of the orchestra. The fault was not due entirely to the arrangements for ventilating and heating, and was soon partly remedied, but the spaces around the valves in the cylinders and the sizes of the outlet tubes above the gas burners were much too large to work properly in cold weather. There were three coils of pipes on either side of the building and two in the corridor leading thereto, whilst two coils were fixed on either side of the gallery which ran on three sides of the building. Fresh air inlet gratings faced each coil, but the area of these in the aggregate was much less than that of the outlet spaces. It will be seen from the drawing that Nos. 1 and 3 of the outlet tubes permitted great volumes of cold air to descend, and No. 3 acted invariably as an inlet. The main entrance was at B, and when the door was open, the pressure of the air going in under the gallery caused the centre burner to act powerfully as an outlet. When testing the volume and action of the intakes behind the coils, A A, of hot water pipes, it was noticed that the instrument stopped for an instant, then reversed and stopped again for some seconds. Thinking something was wrong with the instrument the tests were repeated, but with the same results. A pressure gauge which was placed in another part of the building was watched, when, to the author's astonishment, it registered more pressure *within* than there was outside the building. As the instrument registered the same excessive pressure at intervals of about a minute, and the instrument was observed at frequent intervals, there was no doubt of its accuracy. Further experiments showed that the building, which was very high, had a large excess of outlet area in comparison with that of the inlet. The outlet space was so considerable that the tubes over the sun-burners, 1 and 3, nearly always acted as inlets,

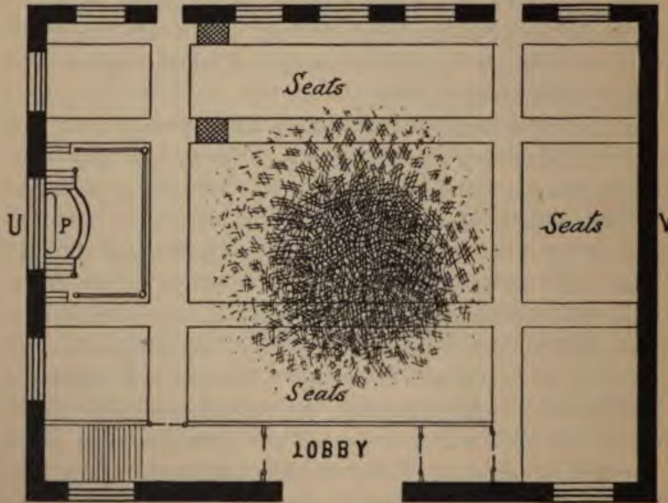
and that for a second or two every minute cold air poured down No. 2 also. After a deluge of cold air had descended, it became warmed, and a powerful up current was formed in No. 2, whilst No. 1 sent out much air, and No. 3 did not let in quite so much. When the up current ceased somewhat, and the velocity in the outlets weakened, great volumes of cold air descended, and this being so cold and heavy, and falling through so great a height, 60 feet or more, compressed the air in the building so much that, in consequence of the elastic nature of the air, the pressure inside the building actually exceeded that of the outside air for some seconds. When the upward movement began again, it proceeded so rapidly that No. 2 burner flared greatly and became partly non-luminous for some seconds. The intermittent action of the air currents in this hall is already referred to on page 15.

The ventilation of such a building would be much improved if the outlet space was under proper control, even with the arrangements shown, and the air inlets provided; but it is almost impossible to get the warmed air to travel from the sides to the centre of a wide building, and it was suggested that a hot air grating should be provided throughout the length of the centre of the hall.

Fig. 15 was a large chapel seating 1,000 persons. It had galleries, but these are not shown. There were two sun-burners and a central opening, D, in the ceiling to afford additional outlet for the foul air in summer. The building was ceiled at the wall plate, and about 33 feet high to that point. After new sun-burners were erected, a severe down draught was experienced, but the gas flames gave little indication of the sources from which the cold air descended. It was found, on examination, that there were air spaces around the tubes of the burners and very considerable interstices around the central opening. These poured down large volumes of cold air when the outside temperature was low, giving rise to most unpleasant draughts. The chapel was



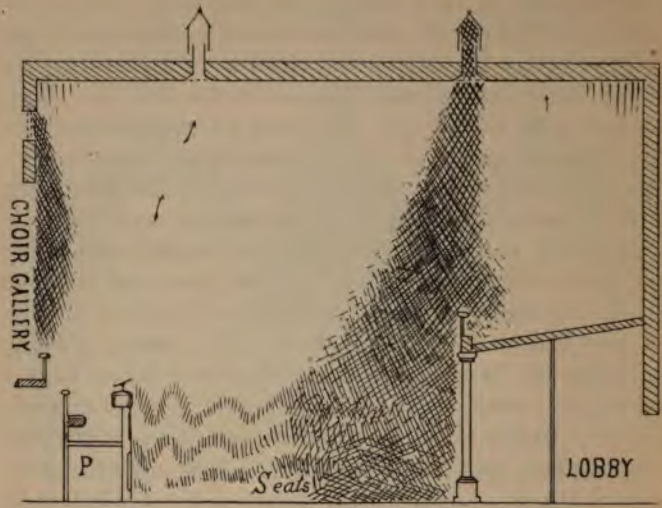
SECTION THROUGH U V, FIG. 15



GROUND PLAN, FIG. 15

heated by hot air from one grating, and some idea of the difficulty of dealing with buildings heated in this manner may be formed from the experience gained in this. By carefully closing the excessive outlet spaces in the roof, the down draughts were cured, and there was no apparent leakage from the ceiling when the outside temperature was at 40° F. This arrangement, however, by adding to the ventilating power of the building, caused the sun-burners to place the air inside under considerable tension, the consequence being that much cold air came in around the doors and windows as well as a largely increased proportion of fresh air through the inlet to the hot air apparatus. The grating through which the hot air ascended was of small area for so large a building, the result being that the heated air shot upwards with considerable velocity in the direction of one of the sun-burners which was nearly overhead. This upward movement of the air caused the gas flames of the sun-burner to flare and flicker so considerably as to divert the attention of the audience. As the authorities did not see their way to furnish a more suitable heating arrangement at that time, and this flaring of the gas flames must be prevented, there was no alternative but to reduce the ventilating pressure on the building, and this was done by allowing more cold air to fall from the ceiling, but at the same time so distribute it as not to give rise to unpleasant down draughts. This sort of compromise equalised matters, because the air rose from the grating with less velocity; but there was, obviously, less fresh air coming into the building. This is another illustration of the necessity for warmed air being introduced through a number of small apertures in the floor of a building, and not to come in one volume at one point. If due provision were made for fresh warm air, the ventilating power of this building could be used to fair advantage.

Fig. 16 is a church seating 700 persons, and over 40 feet high from the floor to the top of the roof. The roof was open



VERTICAL SECTION THRO. U.V. FIG. 16

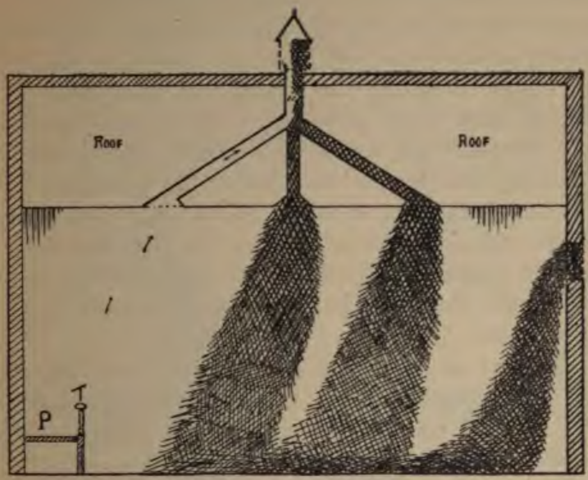
GROUND PLAN, FIG. 16

to within two feet of the ridge, and was carefully plastered between the main rafters. The building was lit by electricity, but jets of gas were fixed at intervals above the lower bond of each principal. There were two ventilators upon the roof of a "self-acting" type, and these, at their lower ends, were shut off by lifting plates about two feet square. Owing to the large area of these plates, and to the considerable spaces around them, much air leaked in; and, in cold weather, when the temperature of the air outside was 40° F., a severe down draught, at intervals, was experienced from the one shown in Fig. 16, although the valves of both ventilators were closed. It was evident that the cracks and fissures in the plaster, or between the plaster and the rafters, were of considerable area in the aggregate. This is the church referred to on p. 65 as having a large volume of fresh air coming in through the inlet of the hot air apparatus, shooting up in a nearly perpendicular current.

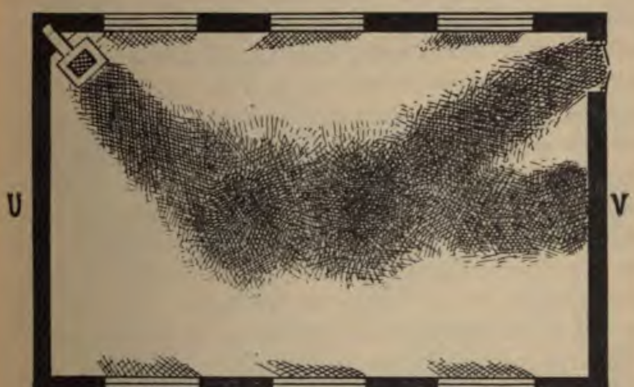
This large volume of heated air escaped around the ventilator almost directly above it, and through the crevices, leaving so much ventilating power upon the building that the velocity through the outlets was considerable at the time when the other ventilator acted as an inlet. To illustrate the large volume of fresh air warmed which came into the building, it may be mentioned that when a very delicate anemometer was held above the grating down which the cold air in the church ought to circulate so as to be warmed before re-entering the building, little or no movement was perceptible. It was noticed, however, that there were two currents in the warm air grating, namely, a warm up current of high velocity and a lesser down current of cooler air. In consequence of the warmed air from the grating ascending so rapidly, it was not possible to open the plates of the ventilator, No. 2, throughout the winter and spring seasons when the heater was at work. If the temperature of the outside air was 50° F. or less, powerful intermittent air currents were at once formed

if the valves were opened very little. The caretaker had moved the lever which was supposed to close the valve and cut off the fresh air inlet, but the valve did not act, and he was not aware of the huge volume of fresh air which was coming in. This instance may be unique, perhaps, and in considering the effects which resulted, it is necessary to remember that the three-fourths of the ventilating power of a building which is generally used up in forcing air around the doors and windows was not wasted in this case, so that much of the total ventilating pressure was available for further ventilation. Under these circumstances, the velocity of the air in the outlets was considerable at one end of the church, whilst at the other end cold air streamed in to partly equalise and reduce the appreciable ventilating pressure which remained. Had the warmed air been introduced through a considerable number of small inlets in the floor instead of through one large opening, the ventilation would have been much improved. The ventilators required valves which would perfectly close the apertures.

Fig. 17 is a lecture hall, ceiled just above the centre bond of the principals, and there were three openings through the ceiling having gratings as shown. The three tubes from the gratings joined into one at a point some five feet from the top of the roof, and there were silk valves inserted with a view to prevent down draughts. When the hall was examined the silk valves did not act, because down draughts were more or less continuous, and very unpleasant in cold weather. The hall was heated by a large stove in the corner of one end, and as the heat from the stove was generally very insufficient when the temperature was low, jets of gas were lit which were fixed at intervals upon the iron ties forming the lower bond of the principals. Much cold air entered from the doors and from a high grating at the back, sweeping along the floor to the stove. The stove itself admitted a little warmed fresh air, but this simply rose with the air warmed by



VERTICAL SECTION THRO. U.V. FIG. 17

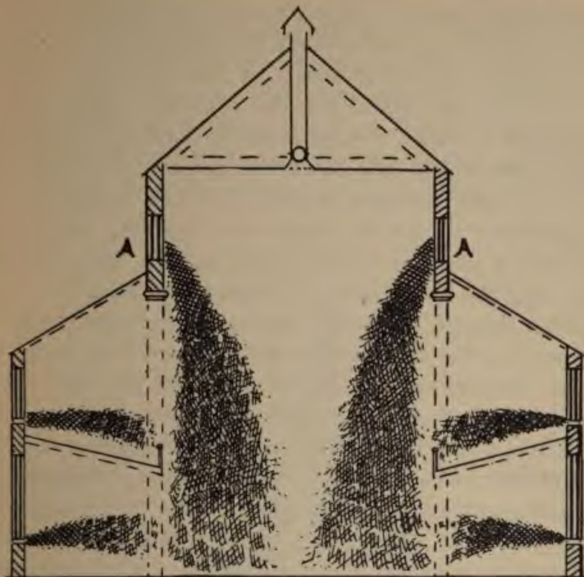


GROUND PLAN, FIG. 17

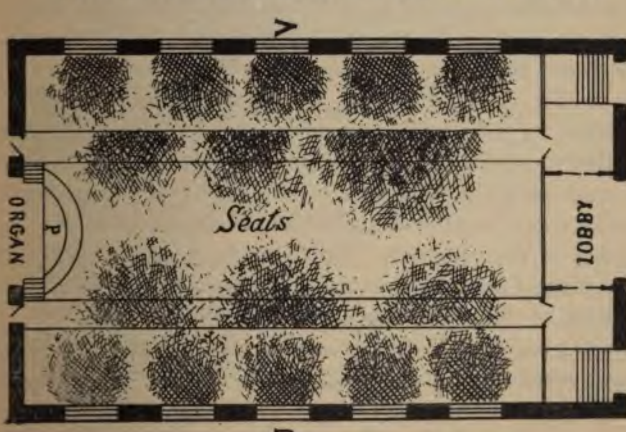
the stove generally, and was pressed forward and upward by the current of cold air moving in that direction. The warmed air chiefly entered the first tube, and found its way out as shown on the drawing; the second and third tubes acting chiefly as inlets when intermittent air currents were once begun. The building was lit by electricity, the incandescent lamps being held by the iron ties of the principals. This hall was an illustration of the failure of silk valves for regulating the volume of air which the ventilator has to carry. They were disarranged when the ventilation of the hall was examined, and the latter, bad as it was, was much benefited in consequence.

In the case of a large and well-built school and classrooms, the assembly hall had a central louvre outlet below which the silk valves were arranged. When examined, these silk valves were large and closed so thoroughly that in consequence of their weight and the fact of the hall being proportionately low, the valves were rarely lifted unless the temperature of the air outside was below 45°. During the spring and autumn months, if the temperature of the air outside was 50° F. or more, they did not act at all, and the condition of the ventilation was bad in the extreme. The inside of the roof of the hall was carefully plastered, and there were few crevices or interstices in it, so that it was one of the most difficult halls possible to ventilate in moderately warm weather. Silk valves or valves of any kind should not be used in outlet ventilators for public buildings. Delicate valves are required in chimney breast ventilators, and the above remarks do not apply to dwellings. They do apply, however, to the classrooms of schools, as the reduced pressure in these rooms will not allow the use of mica, silk, or any other valves in the outlet shafts.

Fig. 18 is a rough sketch of a well-known place of worship in London. There are three ventilators on the roof, and the building is ceiled near the wall-plate. There



VERTICAL SECTION THRO. U.V. FIG. 18

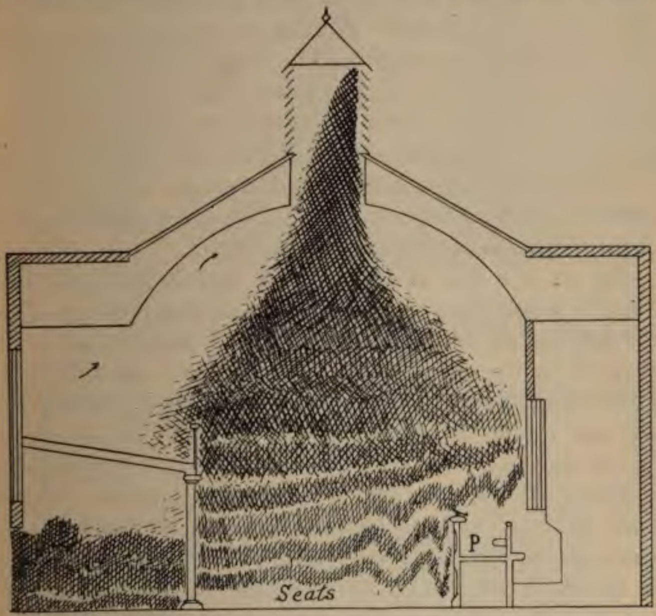


GROUND PLAN, FIG. 18

is a movable pane in each of the highest windows or lights on either side of the building, shown at A A, and as these lights are fixed about 10 feet from the ceiling, they are used as outlets for the foul air; but, in cold weather, half of those opened admit a flood of untempered and frigid air, which falls down and spreads out like a wet blanket for some distance around. On one occasion when the temperature of the air outside was less than 40° F., the outlet window panes referred to were opened wide, but notwithstanding the most persistent attempts to admit air from the outside through the lower openings in the windows above the gallery, and through those beneath the windows under the galleries, the atmosphere in the building was in a most see-saw condition. At one moment deluges of cold air descended, and at another there was an upward movement which caused the air to be drawn through the window openings in thin, cutting streams, necessitating the neck and head to be protected by coat collars and other contrivances. Large box openings were made in the window sills, and these belched forth dense volumes of frigid air. There was no attempt to ventilate. A very little heated air from a stove or two underneath entered the building, and most of the heating was done by lighting the gas burners used for illumination some hours before the audience arrived. Although a large hall, seating 2,000 persons or more, there was practically no provision for admitting warmed air near the ground level. The fact that this church was crowded Sunday after Sunday was most eloquent testimony to the ability of the preacher, because there was neither ventilation nor comfort for the majority of the audience. The church could be ventilated through the floor from the rooms underneath, but the present condition of the ventilating and heating is very bad.

Fig. 19 is a large building with seating accommodation for 1,200 persons. It is of considerable height, especially in the centre, which forms a large dome, and this is crowned

with one huge louvre outlet above the centre of the dome. During cold weather, air from the outside pours down the large opening under the louvre turret at intervals of a minute or less, according to the temperature of the air outside, upon the heads of the audience. The descending air is slightly though imperceptibly warmed by the gas flames over which

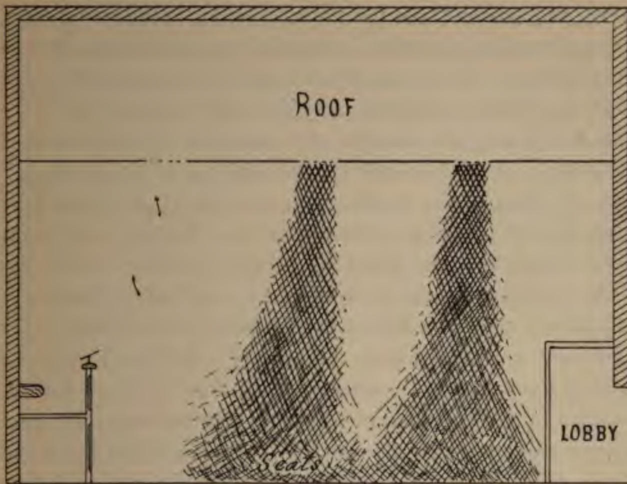


VERTICAL SECTION, FIG. 19

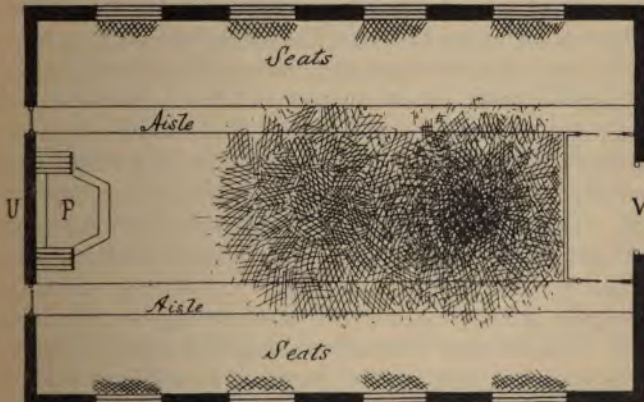
it has passed, and by the products of combustion with which it is mingled; for gas flames are used at the top of the dome immediately under the outlet to assist in forming an up current. The air coming in from the front doors forces against the current descending from the dome, and the air near the heads of the audience is pressed forwards in the direction of

the pulpit, P. A nearly horizontal and forward movement of the warm air vitiated by the breath of those sitting behind is then experienced for some seconds, succeeded by an upward current when the cold air which descended from the dome had become heated, and a similar state of things was repeated at intervals. It was only during the wave-like pulsations of the air and when there was a movement upwards that there was any appreciable decrease of pressure in the building. Owing to the height of the dome, and the large area underneath, the form of the intermittent air currents was that of the up and down movements of the plunger of a pump chiefly. The large outlet in the dome should have two valves—one to be closed in cold weather, and the other capable of accurate adjustment, and much warmed fresh air ought to be admitted near the floor level.

Fig. 20 is a type of many of the chapels and halls built forty or more years ago, before the necessity of conveying the foul air out of the building through metal tubes, which passed from the ceiling to the top of the roof, was recognised. These buildings were ceiled at the wall-plate, and the foul air was simply admitted through gratings into the roof. If the building was large there were several gratings, but in nearly all cases the area of the outlets into the roof was from 5 to 20 times as great as the area of the inlets for fresh air. In the winter, two out of the three openings shown in the sketch poured cold air into the building at intervals, and if a door was opened wide for a second or two and an up current started, a few seconds after the door had been closed a re-action occurred, and a great downpour of cold air supervened. Whilst the door was open, the movement of the air was naturally in the direction of the pulpit. The chancels in most churches, the pulpits in most chapels, and the platforms in most halls are at the end farthest from the main doors. The front of the building, therefore, is usually most exposed to the wind and pressure in the open atmos-



VERTICAL SECTION THRO. U.V., FIG. 20



GROUND PLAN, FIG. 20

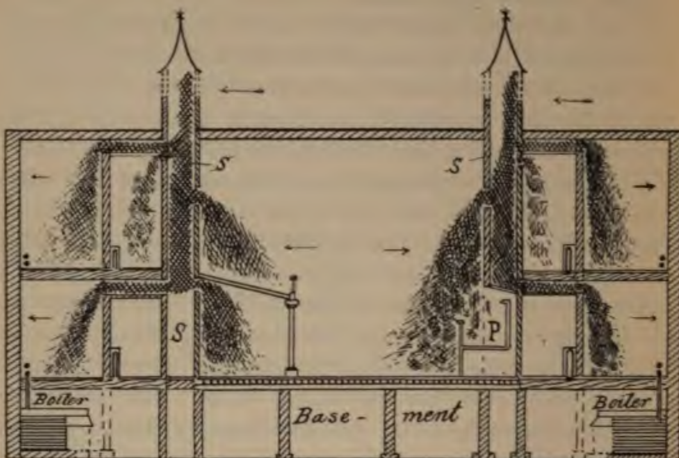
phere, and, under these circumstances, in the cases of chapels and halls especially, the leakage of cold air from the roof occurs more at the exposed end than at the other. Generally speaking, therefore, the opening near the door will be the one from which a down draught will be chiefly experienced, and the movement of the air in these buildings is usually from the front to the back—from the entrance door towards the pulpit or the platform, as the case may be. Hence it often occurs that whilst the preacher experiences the warm current of air moving towards the pulpit, he also has to breathe the atmosphere already vitiated by the breath of the audience.

In those churches where the roof is ceiled until the second bond of the principal is reached and there are high buildings near the pulpit end, a down draught not unfrequently occurs through the gratings above the preacher's head. This is usually induced by the action of the wind, which upsets our calculations as well as the ventilation of a building. The movement of air through large openings into the roof is very erratic and rarely follows any fixed rule, as it is at the mercy of the wind and other currents in the atmosphere of the roof above the ceiling. The general effects of gratings which open into the area of the roof are discomfort in winter with serious colds, but in summer and in weather when the temperature of the air outside is 60° F. they aid ventilation, and some buildings of this kind are remarkably cool in hot weather, chiefly those, of course, in which the ceilings are high. Neither the ceilings nor the gratings opening above them are to be recommended, and chapels and halls are rarely built like this now. Where such gratings exist and intolerable draughts are experienced, valves or covers of wood which are close-fitting should be fixed near the gratings in the roof and these opened as much as will best suit the ventilation during cold weather.

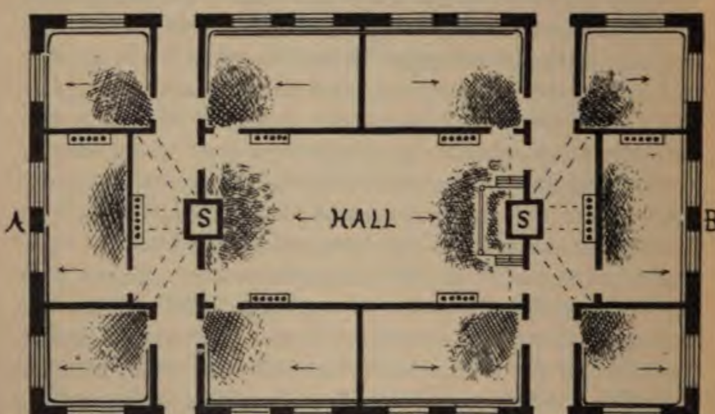
Mission halls and low buildings without any roof ventilation and dependent upon the windows being opened in winter,

are traps for propagating pulmonary disease; and whilst the free will of the subject should be as far as possible respected by the State, it is a question whether some supervision by the Local Authority should not be exercised over all buildings where the public assemble, in order to secure the comfort and well-being of the audience, and the preservation of health.

Fig. 21 is a rough drawing which represents the class-rooms and assembly hall of a public school. There are 10 classrooms on each of the two floors, and there is a large air outlet in every classroom close to the ceiling at the nearest end to one of the two shafts, S S. These shafts are of large area, 7 feet square, the idea being that the larger the shaft the more air would circulate when the temperature of the air outside was moderately warm. The prevailing winds blow from A to B. In consequence of the large area of the shafts, down currents prevail in cold weather, and intermittent air currents are formed in the large hall, and during windy and cold weather in the classrooms also. The building is heated by hot water pipes and coils throughout; and the fresh air comes in beneath the windows and through gratings in the outer walls. When the wind blows sharply in cold weather from A to B, the air inlets and gratings in the end of the wall A are under increased wind pressure, and vast volumes of air get in through them giving rise to much discomfort. To obviate this, the valves of the gratings are frequently closed, and become further clogged with dust in consequence. When the deluge of air got into the class-rooms in the end A, the air outlets swept much foul air into the air shaft, S, and, as the volume of air admitted into the classroom through the inlets on either side was decreased by reason of the aspiration of the wind upon them, the foul air which travelled into S from the classrooms at the end, A, passed back to those on either side of the building and into one end of the hall, forming down currents which at times drove the inlet air back into the outer atmosphere. During



VERTICAL SECTION THRO. A.B., FIG. 21



GROUND PLAN, FIG. 21

this time the air inlets which opened into the two sides at the B end, and into the B end itself, were under reduced pressure, the consequence being that one minute the air in the classrooms was stifling hot, the next a deluge of cold air mixed with foul air products rushed into those classrooms which had the largest outlets, and where the aspirating action of the wind was most pronounced. The intermittent air currents so formed were very troublesome and unpleasant.

The arrangement of the classrooms and the central hall were very good. The distribution of the hot water apparatus was passable, and the carrying over of the air outlets from the classrooms to the shafts, S S, very judiciously planned. After inspecting the building one could not help being pleased to see everything in such order, but appearances are often deceiving. One of the chief faults in the ventilation was the frequency and ease with which down draughts occurred in the shafts, S S, which were of much greater area in the aggregate than the inlet gratings when the wind was blowing from any quarter, and if any of the inlet gratings were shut the mischief was naturally aggravated. The considerable height of the air shafts made the down draughts and intermittent air currents more pronounced and unpleasant. The shafts, S S, were not properly protected from wind effects at the top, and the larger shafts of this kind are, the more such protection is needed. Some appliances were required to reduce the area of the shafts at the top during cold weather, and this last precaution was very necessary. The air inlet gratings should be protected from wind effects, and proper precaution taken to make sure that a strong wind did not disturb the direction of the air current in the outlets to the shafts. The area of each outlet from the classrooms, and from the hall, required to be adjusted according to the tension which was necessary, and according to the extra friction entailed by carrying the outlets over into the shafts from the classrooms farthest away—a very important precaution. Heat

applied in each shaft just above the air outlets of the class-rooms on the ground floor would render the air current in the shafts more powerful, and less sensitive to the action of the wind, but a good fan in each shaft would be still more serviceable.

From what was said in Chapter IV., and the illustrations given of various buildings, and taking into consideration the further drawings and references in this chapter, it is thought that the types of most public buildings have been mentioned, whilst the action of the wind, and the intermittent character of the air currents, have been pointed out in detail. If the caretaker will consider these movements of the wind, and of the air inside buildings, and carefully compare the results with those which take place inside that over which he has charge, it ought to be possible to remedy some of the evils which lead to unpleasant down draughts.

CHAPTER VI.

HOW THE VENTILATION CAN BE IMPROVED IN BUILDINGS ALREADY ERECTED.

CONSIDERATION will be given first to the exit spaces and ventilators in or above the roof. Many churches like Figs. 12 and 13 are better ventilated than those which have ventilators in or upon the roof, and it would appear that the crevices and interstices in the boarding or plastering between the rafters were ample in total area to afford exit for all air getting into the building at the floor level. And this is the case in nearly all high buildings unceiled to the second principal bond. Where there is no ceiling, and the rafters are simply covered with match-boarding, the area of the outlet crevices in the roof will be generally far in excess of what is wanted in cold winter weather, no matter whether the tiles are boarded underneath in addition, or whether the slates have their joints plastered. The great heat absorbed by the slates during the summer simply cracks all the plastering, whilst the woodwork shrinks greatly and match-boarding is like a sieve to air under slight pressure. Where the roof has had felt laid upon boards under the tiles, and the joints of the felt have been made air tight, the air outlets will be under command; but, owing to defects in joining the felt, most buildings so provided have much outlet spaces notwithstanding.

Whether there are ventilators in the roof or not, attention should be given *first* to the condition of the building

during very cold weather—say at 40° F. or less, in order to see whether the crevices in the roof are too many in themselves to carry off the foul air when the outside temperature is so low. If the crevices are too numerous, some of them should be stopped up so that there should be no down draughts or perceptible air movements at 40° F. The down draughts generally increase in new buildings which are unceiled, and in which match-boarding is employed, by reason of the continued shrinking of the timber. Thick brown paper and strong paste and glue can be applied with effect, and the wet paper should be wrinkled loosely so as not to dry strained, or crack when dry, but it is unwise to paste over the crevices promiscuously, as it is best done in that portion of the building where the down pressure is most strongly exerted.

In many churches and other buildings hot water pipes are laid below the floor, and some provision made to let fresh air come from the outside; but, in consequence of the roof being timbered inside and shrunken by the heat, cold air streams so freely from the roof in the winter that the fresh air inlets below the pipes either do not act at all, or only fitfully and at intervals. The audience is thus caused to breathe the raw air from the outside, tempered only by being mixed with the warm exhaled products which are caused to descend to the hot water pipes to be further heated, and sensitive persons suffer repeatedly from colds in consequence of the swirl and up and down movements in the air.

It is most essential, therefore, that the combined area of the exit crevices in the roof should be ascertained and their outlet value determined, when the temperature of the air outside is low, so that proper regulation shall be made. If it is found when the ventilators are closed that the area of the cracks and crevices is sufficient or excessive, the provision which is made for closing any ventilators on the roof should be carefully examined in order to make sure that no undue

leakage occurs from deficient valves, and that arrangements are made for closing them perfectly. As the valves for closing ventilators are generally provided by the builders, they are usually of the pattern known as the butterfly valve, Fig. 22, which is a plate of iron cut to fit the ventilating tube, and having an iron rod across its diameter which passes through the walls of the tube, so forming pivots whereby the iron plate can be tilted from the outside. The valve is

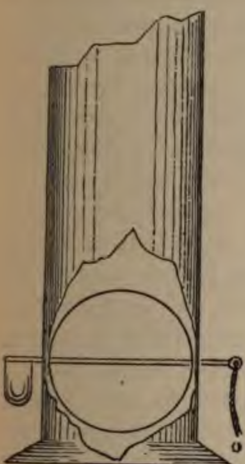


FIG. 22

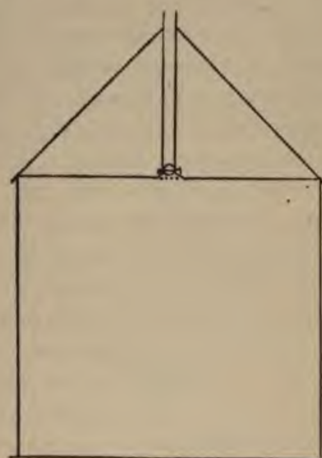


FIG. 23

generally weighted so as to be self-opening, whilst it can be shut by pulling a rope attached to a crank on the iron rod shown above. The valve opens as soon as the cord is released, and is shut when the cord is strained tightly, being prevented from turning round by a stop riveted in the walls of the outer tube. But how seldom is this tightness obtained! Careless straining of the cord leaves perhaps one-fourth of the area of the tube open, and down draughts are frequently

so caused. Then, in the majority of instances, the valve fits very slackly, because it was thought of slight importance, and great volumes of air leak around it in cold weather.

In many instances where ventilators are fixed, the roof is ceiled either at the second principal bond or at the wall-plate, and the metal tubes of the ventilators may consequently be from 8 to 20 feet in length at their termination above the roof. For the convenience of shortening the ropes, and getting at the valves, the latter are almost always fixed at the lowest end of the tubes, the result being that from 8 to 20 feet of cold air column above the valve is a perfect nuisance, when the velocity of the air escaping through the ventilator is low, or when the area of the tube is reduced by closing the valve. Let Fig. 23 represent a building ceiled at the wall-plate, having a ventilating tube which measures 18 feet in length from the ceiling to the top of the roof. The hall is 30 feet high, and if the valve, instead of being fixed at the bottom, were placed at the *top* of the tube, and the cracks and crevices had been properly adjusted, the ventilating power of the building should be measured by a column of air equal to 30 + 18 or 48 feet in height. But with a valve at the bottom of the tube, the 18 feet of ventilating pressure can only be added when the valve is fully open and there is enough air passing through the tube at sufficient velocity to keep the outer air from entering. If the valve is one-third open, two-thirds of the 18 feet tube or more may be filled with cold air, and the greater part of the ventilating pressure will be lost. And this is neither the only nor the most serious fault, perhaps, since air being so very elastic, the cold air in the 18 feet of tube when the valve is less than half open would compress and overcome the heated air, and give rise to alternating air currents which are so detrimental to ventilation. All roof ventilators, therefore, should have appliances for closing them perfectly, and these are best fixed

at the mouth of the tubes at their upper end. Butterfly valves are most unsuited for the purpose, because when partly or even full open, they favour the formation of the down as well as the up current, owing to the manner in which they divide the tube.

The rope connecting the valve of each ventilator with the part of the building where it is to be fixed and regulated should be of steel strand wire, and the lower end of the wire rope should be attached to some arrangement connected with an indicating board showing how far the valve or cover should be opened according to the *temperature outside the building.* If some such arrangement is not furnished for the caretaker, it is not possible for him to gauge the ventilators and regulate the air outlets so as to prevent down draughts, and to place the building in the best condition for ventilation.

The question might be asked, however, "Why not close up the ventilators permanently or get rid of them altogether, if the area of the crevices in the roof is sufficient?" The ventilating power of a building depends as much upon the temperature of the air outside as upon the height of the building. When the air outside is 35° F. and the air inside is 65° F., there is more than enough power afforded by the difference in density between the two air columns to ventilate a high building, and force the foul air through the cracks in the roof. When, however, the outside temperature is 55° F., and the artificial heat is discontinued, the friction with which the foul air meets in passing through the crevices in the roof, reduces the volume of air which gets into the building very appreciably, hence it would be a decided advantage to have ventilators on the roof through which the foul air could escape freely and without encountering much friction. Furthermore, the heat of the sun in the summer warms the roof so greatly that ventilating tubes materially assist the upward current of the air, and, for these reasons,

it is desirable to have ventilators, provided they can be closed perfectly.

Old-fashioned louvre ventilators are not desirable unless they can be nicely regulated, because, if large enough for summer ventilation, the leakage of cold air during the winter months is sufficient to cause severe down draughts, and give rise to up and down movements of the air in a building. Where a large louvre is fixed, from which cold currents of air descend, and where gas jets are used to assist the up current because the ventilation of the building is top heavy, such defects can be cured by a suitable double valve arrangement for regulating the outlet area in cold weather, and connected with an indicator board for accurate adjustment according to the temperature of the air outside. If the caretaker possesses an instrument for detecting down draughts, it will be possible for him to regulate the valves and avoid down currents of air even in the coldest weather, if proper arrangements have been made for adjusting and closing the valves.

Some buildings are fitted with silk or mica valves underneath a louvre arrangement. The gas jets are distributed, necessarily, inside the building, and not immediately under the ventilating shafts, but the force or pressure for ventilating is not enough in low buildings to raise the valves when the outside temperature is above 50° F.; and such valves or flaps are decided and serious hindrances to ventilation after artificial heat has been discontinued in the spring and throughout the summer and autumn. The ventilation would be much improved by removing the valves, and placing a tube of reasonable diameter provided with a close-fitting cover at the upper end and connected with an indicating arrangement as already mentioned, or, should the opening be very large, by adopting a double valve, the smaller being for winter and the whole opening for summer use.

Some of the roof ventilators upon the market are said to

entirely prevent down draughts. It is difficult to assume that the makers are ignorant or that they do not know that the statement is untrue, but such assertions are as false as they are misleading; and, furthermore, if the ventilators possess any real exhaust power they must cause down draughts in consequence of the general lack of inlet air.

What is wanted in a roof ventilator is a covering to prevent the rain falling into the inside tube, and one which instead of suddenly exhausting the air will, on the contrary, as perfectly as possible equalise the pressure which may have been disturbed by the force of the wind, and the air currents above the roof. If suction is to be applied in the roof of a building then it should be done by mechanical means alike continuous and reliable, and not dependent upon the vagaries of the wind. In the absence of such mechanical aid, nothing should be allowed to interfere with the ventilating pressure of the building, which cannot be assisted by any form, fashion or shape in the ventilator itself.

So much was said of late years about the "self-acting" properties of pneumatic ventilators that the real ventilating force available to ventilate a building was rarely mentioned. When so-called natural ventilation was referred to it was generally in relation to the aspiration of the wind. Now that the aspirating action of the wind is known to be so erratic and uncertain, more attention is being given to the ventilating force upon every building which results from heating the air inside, and which is increased by the heat from the lungs and bodies of the audience as well as by the moisture in the breath. This ventilating force is reliable. It varies in strength according to the temperature of the air outside, but if this ventilating power is studied and made use of effectively, after placing the inlets and outlets under proper control, the caretaker ought to be able to ventilate his building in a much more satisfactory and *certain* manner than heretofore.

From what has been said, it is evident that the first thing to be done to improve the ventilation of present buildings is to provide warm fresh air and introduce it at the floor level. At first sight this seems an insuperable difficulty in most instances. Where hot water pipes are laid below the floor in the aisles, etc., the inlet air shafts generally enter and meet the pipes at too great a distance from each other, and the difficulty is to warm the volume of air which rushes up all in one place. The lower pipe should be covered with finely perforated zinc so as to cause the cold air to be more evenly distributed, or, if the air inlet is large, sheets of perforated zinc should be curved downwards and placed under the iron grating above the pipes, then the weight of the gratings will keep the zinc sheets level on their outer edges. The perforated sheets must be cleansed frequently to prevent choking. A little care in this respect will do much good, and, by nicely regulating the outlet spaces in the roof to prevent the ventilation being top heavy, the results will be fairly satisfactory. On examination, it will be found that the fresh air inlets are generally closed, because of the draughts experienced in winter for want of the air being distributed all along the pipes.

Where air is heated inside the building by passing down one grating over hot iron plates and up another grating, very little can be done to improve matters. If the floor of the building lies close to the ground, hot water pipes should be laid if possible, and a large volume of air introduced and carefully distributed over the whole length of the pipes, which should be laid in front of the communion rail, and in other convenient spaces in the aisles and near the walls. The outlet spaces at the top of the building should be carefully regulated, for, if the ventilation is top heavy, the warmed air arising from the pipes will simply shoot upward towards the roof and cold air descend in the centre of the church between the aisles. It is most important, therefore, that the roof outlets shall be well regulated.

When a building has been raised a few feet above the earth, it may be possible to send hot air (from a battery of pipes below and outside the structure) underneath the building. This is the most desirable method, as it is possible, then, to subdivide the air as it enters through the floor far better than it can be done from hot water pipes laid below the aisles. There is generally a width of 20 to 30 feet between the two aisles or footways occupied by the rows of chairs or seats as the case may be, and the centre of a building will not receive a proper air supply, as the tendency of the fresh air arising as it does from the pipes under some pressure and velocity is to go upward too quickly to spread much laterally.

A large number of buildings used for religious purposes have schoolrooms underneath with headroom from 10 to 16 feet. It is easy to ventilate a building which has a schoolroom underneath, but it is not so easy perhaps to convince the authorities that the breath of the children can be swept away and the schoolroom used as a warm fresh air distributor for the building above. Where there are schoolrooms underneath and ground enough adjoining to place a battery of pipes to warm the air before it enters the schoolroom, it is possible to ventilate the church over it almost perfectly. In many Nonconformist churches "Pleasant Sunday Afternoons" are held, and, if the building can be cleared of breath and foul air before the evening service, it stands to reason that the schoolrooms can be likewise purified, and the latter can be done more easily because the ventilating power of the building will be increased by the additional height of the schoolroom—a most appreciable and useful adjunct. The ventilation of schoolrooms underneath chapels and halls is usually very bad indeed, because the headroom is so low, but if the ceiling and the floor of the building above were perforated with sufficient openings, the ventilation would be vastly improved. If the schoolroom is ceiled, it should

have strips of coarsely perforated zinc run across the joists at intervals, and the air should pass through inlets in the floor to supply each pew. Other inlets should be fixed in the aisles, around the pulpit, in front of the communion rail, and, if possible, underneath the floor of the galleries, if there are any, into each pew there. The inlets should stand about two inches above the floor, and should be covered at the top to prevent the air shooting up, and also to keep them clean. No valves should be supplied whereby the pew occupants could close the inlets. Care should be exercised, however, that the inlets should be capable of being regulated underneath, so as to set them more or less open at first, in order that those nearest to the incoming air should not admit more than their share.

Neither sentiment nor prejudice ought to prevent the use of schoolrooms for the purpose indicated, and, if proper attention is given to the roof outlets of such buildings, then the ventilation will not require mechanical aid, and, even in the worst weather, it will be passable.

CHAPTER VII.

MECHANICAL AND HEAT-AIDED VENTILATION.

AT the present time it is difficult to say which is most generally advocated, mechanical, or so-called natural ventilation. Now that the electric light is becoming so widely adopted, and electric currents can be obtained in small towns even, it is possible to get mechanical aids to ventilation in the form of electric fans, which, during the next fifty years, will revolutionise the ventilation in new buildings. Some of those who sell appliances for ventilation say that mechanical aids are of no value, and those who sell fans say, naturally, there is nothing like them for ventilating buildings. Common sense ought to give its verdict in favour of the fan, but common sense speaks of a thing as it finds it, and not always in accordance with its deserts. The fact is, up to the present, mechanical-aided ventilation has not proved successful, and, as so-called natural ventilation does not play quite so many pranks on account of its lesser power and cheaper working, it still meets with considerable favour. It is only fair, however, to enquire why it is that fans have been so unsuccessful, and it may assist one in forming a fair conclusion if the ventilation of a building having a fan in a low turret on the roof were examined to see wherein the defects lay. The building in question was large and ceiled at the wall-plate, and was about 35 feet high to that point. A large outlet in the centre of the ceiling communicated with a fan immediately above and underneath the turret upon the

roof. This building is not given as a type of ventilation by mechanical power, but it will illustrate how such aid is rendered inoperative. Before the fan was fixed in this building, very little attempt had been made to introduce fresh air, and no provision was made for warm fresh air to come in at the floor level. As soon as the fan started it was found that the tension inside the building increased and became considerable, the result being that the leakage of air around doors, etc., caused severe draughts. The moment a door, either on the ground floor or in the gallery, was opened, floods of cold air rushed into the building, and the draughts were most unpleasant and disappointing. To obviate these, the doors were carefully fitted with felt to exclude the draughts, and glass screens were placed in front of the doors leading to the galleries, and by the side of the aisles adjoining the doors downstairs. When the chinks around the doors had been stopped, and the openings in the windows adjusted, so thoroughly were the draughts prevented, that the building was fairly air-tight; and it was really a mystery where the authorities expected the fresh air to come from. Worse draughts, however, were to be encountered. The fan being able to get only a very little air from below, exercised its power in placing the atmosphere in the building under the greatest tension possible, and it became so sensitive that the sitting down of the audience after standing brought a flood of cold air down through the central opening in spite of the revolving fan; and even when a *slight* wind was blowing, the building became subject to the intermittent air currents which have been already described. To obviate these down draughts from the central outlet, the fan was slowed down somewhat, and jets of gas were arranged just above the ceiling level under the outlet with a view to assist the up-current. During the winter, most of the air getting into the building came down the central opening in fitful gusts at intervals. In warm weather, when the movable

panes in each window could be opened, more air was available, both on the ground level and above the galleries. The movable panes were about 14 inches by 8 inches in area, and were regulated by cords fixed close to the seats. Some time ago the author was present at a crowded meeting in the building when the temperature of the air outside was about 53° F., and the fan was revolving slowly and regularly—all the window openings and doors being closed at the beginning of the meeting. The atmosphere soon got foul, and one of the audience opened a ventilator in one of the windows underneath a gallery downstairs. The air shot like an arrow towards the centre of the building, because of the reduced pressure inside, and was of little benefit to those near the opening. Soon afterwards, three similar ventilators were opened in the windows over the galleries, and these likewise shot streams of air towards the central outlet. The fan then obtained nearly all the air it required without much friction through the four openings, the consequence being that very little came in from the crevices around the doors, etc., and the atmosphere in most parts of the building was stagnant and very foul.

Most persons unacquainted with physics would condemn the fan at once as giving rise to down draughts in winter, and being useless just at the very time of the year (spring) when the temperature outside (53° F.) was near its lowest ventilating value, and when, if ever, the fan ought to be of the greatest use. But the fact is, the fan was not to blame, as it did its work regularly, and its best under the circumstances. Mechanical, and heat-aided, or so-called natural ventilation, run upon similar lines, and what is essential to the success of the one is essential to the success of the other. It is no use trying to get air out of a building until provision is first made to let air into it. Had the authorities heated a large body of air, and allowed it to get into the classroom underneath the assembly hall, and then through numerous apertures in the floor into the hall itself, the fan would make sure that the

foul air should be removed through the central outlet. The larger the volume of air coming through the floor the less would be the tension in the building; and when a door was opened the cold air would not shoot across the audience. If this provision had been made there would have been no need for the ventilators in the windows to be opened at all during the meeting referred to, and, with a powerful fan, even in summer time, the atmosphere would be good although the windows were shut.

What has been said about the window openings will show how difficult it is to use them to the best effect even in moderately warm weather when mechanical power is employed. *In the first place it should be made impossible for the audience to interfere with the ventilators in any public building.* One man has fresh air on the brain, and wants every ventilator open, even if the air coming in is frigid. Another, suffering from neuralgia, and having had the sad experience perhaps of sitting near cold air inlets in the school where he was educated, wants all the openings closed. Only the caretaker should be able to get at these ventilators, and they should be adjusted to the best of his knowledge and experience before the meeting commences. In all cases where mechanical aid is at command, the great point is to ensure that air shall be distributed all over the building near the floor level. Openings 14 inches by 8 inches through which air can come into a hall having a fan in the roof are much too large. Every caretaker who has a fan to superintend should be provided with an instrument which would show the difference between the pressure inside the building and that on the outside, in order that he may not at any time increase the internal pressure too much, and cause intermittent air currents, because too much inlet air space has been afforded by the over liberal opening of the window ventilators.

There is no doubt whatever that air inlets brought through and raised just above the floor of the building are the best.

It is folly to object to such on account of supposed dust coming through these floor openings. Buildings kept clean and provided with proper inlets fixed above the floor level are free from dust, and it is only possible to distribute air to an audience in sufficient volume and in comfort in this manner.

The fan referred to was fixed in a turret in the roof, but it is not best in all cases to ventilate by the exhaust method. Where a building is ventilated from below, and the height and area of the mixing chamber are satisfactory, the plenum method, using the fan for forcing air into the building, is sometimes desirable and better suited than an exhaust fan in the roof of a building. In either case, the inlets should be through the floor, of great number and of small area. If the plenum method is used, and the fan is fixed in the basement, it is still necessary to examine the outlet spaces in the roof, as in the case of natural ventilation. If volumes of cold air fall from one end of a structure it may be regarded as certain that a corresponding body of air which has been warmed and sent into the building through the floor is at once expelled upwards and outwards through the roof at the other end before it has done much service in the lungs of the audience. It should not be forgotten that it is not only possible but certain that down draughts and intermittent air currents can be formed even where warmed air is sent by the plenum method through the floor of the building. Whether the plenum or the exhaust method is adopted, no satisfactory result will be obtained until the inlets and outlets are properly adjusted according to the friction and tension incidental to their area and to the part of the building in which they are fixed.

When a building has sufficient inlets through the floor, and full provision made for enough air to enter, the fan will do its work best, and be most efficient for summer ventilation, when it is fixed in the centre of the roof, if the building is high enough, or two fans may be employed if the roof is

somewhat low. The reason of this is that the fan will have a vast body of elastic air to pull upon in the building, and there will be a steady and continuous draw upon the air inlets through the floor; and, although the aspirating influence of the wind will affect both the inlet and outlet air at times very appreciably, the large elastic buffer afforded by the inside area of a building will neutralise the tendency for vast volumes of air to be drawn through the floor inlets at the moment of the greatest air pressure outside, and small volumes at a high temperature to come through when the aspirating power of the wind is most exercised upon the inlet air as it comes from the outside.

The chief value of mechanical aid is that the air can be drawn into a building or forced into it under appreciable friction, and therefore through small apertures. Let us suppose there is an unceiled space under a public hall 10 feet high. Into this space, air is forced by a fan to be heated over hot water pipes, and then sent through inlets in the floor into the hall. If there are six inlets only, of area equal to 3 feet each, these will be very sensitive to every swirl of the wind, especially if the inlet gratings in the outside walls are of large area. It is impossible to prevent wind suction upon air inlets feeding a fan, in many cases, simply because the building is so situated that every forward rush of the wind means a greatly reduced pressure around the building. During the time a strong gust is blowing, the inlet air is checked, and where the inlets through the floor above the heating chamber are of considerable area, the aspiration of the wind greatly influences the main body of air *inside* through these large channels. The atmosphere in the assembly hall of the building becomes attenuated, and its pressure reduced, with the unfortunate result that such a small volume of air passes over the hot water pipes in the basement, that what warmed air does pass through the gratings into the hall is too hot, and the audience experiences the effects of the hot room of

a Turkish bath during every strong gust of wind, and a cold air current during a lull in the storm.

The effect of the wind upon the ventilators on the roof may remedy this state of things somewhat, or may even aggravate them according to the position in which the building is situated.

By a judicious use of the fan to force air through many small apertures into a building, and then out through the roof *under considerable velocity*, the air in the hall or church can be kept from being much influenced by the vagaries of the wind. If the fan is used to exhaust the air from a building, the main point after supplying enough inlet air through the floor is to make certain that no air leaks through the roof to feed the fan, and so render its action inoperative. Where a fan is fixed in the roof, every crack and crevice ought to be stopped. This is not so imperative if the fan is used for plenum ventilation, but the top outlets must be under command, and should not be more than one half the area of the inlets in that case. By such an adjustment of the top outlets it will be possible to use the whole of the natural ventilating power of the building to assist the fan, a power which may be equivalent in cold weather to a velocity of 15 feet per second in the outlets.

For summer ventilation, the fan is most useful, as well as during mild weather in the spring and autumn. By providing extra and larger inlets through the floor in the aisles, etc., for use in the summer in addition to the inlets in each pew, it will be possible to be independent altogether of window openings; and, whilst the fan is working satisfactorily, a far better atmosphere will be maintained with closed than with open windows, because the law is that air, like all other bodies, will travel along the lines of the least resistance; and if the fan can get its air above the heads of the audience in sufficient quantity because the upper windows are opened, it will do so, leaving the atmosphere in the body of the

building almost unmoved. Where sufficient air gets through the floor of a structure, and the fan is doing its work efficiently, the caretaker should be instructed that no window is to be opened even in the hottest weather.

For drawing off the foul air through the outlets in the classrooms and halls of Board and other schools, fans are admirable, providing the heating is done by hot water and not by fires; and provided also warm fresh air is introduced. There is no doubt whatever that mechanical aid is necessary to keep the atmosphere of a school moderately pure in the autumn and spring when the air is too cold to open the windows; but it is feared that with the present arrangements it is not possible to ventilate in summer with closed windows. It is possible, however, by carefully directing the incoming currents, to draw off much of the impure air through the outlets, and so greatly improve the atmosphere by the mechanical aid afforded.

There are numerous fans on the market which are nearly equally good and effective, but there are others which are not so good. For the guidance of those who have not been able to devote much attention to the moving of air mechanically, it may be concluded that any fan having more than 6 blades will give rise to so much friction that it cannot move the maximum volume of air. Fans with 6 blades are better especially if driven at a low speed, but if the blades are curved at the right place so as to grip the air, and are wide enough to do this and deliver the stroke with fair clearance, then a fan with four blades will be found most effective.

Some makers supply heaters with fans combined, and, in some cases, these are useful, especially where room is a consideration. When superheated steam is employed, however, the temperature is high enough to cause considerable oxidation and unpleasant odour, and such a heater is not to be recommended for churches and halls of assembly.

In some public buildings and hospitals, and in many

schools, hot water or steam pipes are used to facilitate the discharge of foul air through the outlets. It is too often forgotten that their effective value depends upon the column of air above the heater, and between it and the outer atmosphere. Where the outlets enter near the ceiling of the ground floor of a building two or more storeys high, heaters are effective, and, where there is a high column of air above them, they can be made to aspirate powerfully; but they are not worth the expense of erecting and maintaining unless that air column measures 20 feet or more. Small fans are much more effective, and, on the whole, less costly.

Where coke or common fuel is burnt in a furnace or arranged so as to give the greatest heating surface for the fuel consumed, and there is a tower or stack sufficiently high to afford good ventilating power, it is possible to assist the outlets of a building very effectively by connecting them with the furnace. The upcast pits of coal mines used to be ventilated chiefly by furnaces in the first half of the nineteenth century, but fans have taken their place since; and for ventilating buildings, furnaces are rarely employed now. Furthermore, it is not probable that new buildings will be erected in which furnaces will be used to remove the outlet air. Not that the furnace is ineffective or unreliable, for this is not the case. Where furnaces have not done what was expected of them it was not their fault, but the want of physical knowledge on the part of those who planned the ventilation. Where the outlets are properly adjusted, and the shafts are so shielded as to be almost independent of wind effects, excellent results can be obtained by furnace action. The furnace has proved its value in the ventilation of coal mines so conclusively that further comment is needless. It is a fact, however, that the majority of ventilating engineers are in favour of the fan for coal mines, and, when efficiently driven, there is no doubt the exhaust effects are more continuous and regular as well as more powerful.

CHAPTER VIII.

HOW TO VENTILATE NEW BUILDINGS.

It rarely happens that the architect of a building has any lot in the selection of the site upon which the structure is to be erected. In the case of a church it is most probable that the site was purchased years before the plans were ordered, and the design may have been selected from a number sent in for competition, the architect himself not having seen the position at all. Under these circumstances, the architect knows nothing of the wind effects upon the ground in question, although it is possible for him to alter somewhat the sizes and positions of the air inlets and outlets. It often happens, however, the church authorities determine that a building shall be erected in strict accordance with the plans, or, as is not unfrequently the case, they conclude that certain spires or towers shall not be proceeded with until there are more funds forthcoming; the result being that the heating and ventilating arrangements are modified and changed to the detriment of the well working of the whole.

In the selection of other sites for assembly halls, town halls, schools and hospitals, the architect has rarely any choice in the matter, so it generally happens that he has to adapt his building to the site, rather than select a site for his building. If the architect aims at appearance chiefly, and this is the principal point in a competition, then everything else has to give way so that the building may be imposing

and striking in design. The comfort of the audience ought to be the chief consideration, but if it has due prominence, the architect will be handicapped in his design. Architects, therefore, have not had much inducement to try and make the ventilation the chief consideration, hence it is, perhaps, that so little real progress has been made in supplying a reasonable volume of fresh air in every part of the building where the audience is seated.

The authorities who are responsible for the selection of a site for a church or any other public building ought to have some knowledge of what they are doing. If the ridge of the roof must run east and west, much will depend upon the side of the road or street where it is to be erected. If the church is to be built on a hill side, much care is necessary to make sure that the prevailing winds do not blow at right angles to it, and that the outlets on the roof shall not be subjected to greatly increased pressure every time a moderately strong wind is blowing.

The same precautions ought to be taken in the case of the sites for all public buildings, and if the authorities are in any dilemma as to the probable results of wind action, advice should be taken beforehand, as it is quite possible that a great mistake may be made for want of some knowledge in the matter. Those buildings which are erected in more or less open spaces are the most subject to the aspiration of the wind, and it is always well to know from what side the inlet air is best taken, and what parts of the building the winds will chiefly affect. Much more attention ought to be bestowed upon the probable action of the wind upon inlets near the ground level. Now that the effects have been described, it is not difficult to find a remedy, and, with the same consideration given to the outlets through the roof, the ventilation of a building and the movements of air in it ought to be much more under command.

One of the first considerations is the height of the building.

No question as to cost should stand in the way of its being *high*. If it were only the increased number of cubic feet of air per head which it will afford at the time the audience assembles, it is worth all the extra cost; but the increased ventilating power which 20 feet of headroom will afford is equal to about 2 ounces of pressure on the square foot during the cold months of the year. Then with 8 feet or more of basement underneath the church for the purpose of forming a heating and mixing chamber, it is possible to get a height of 50 feet from the basement to the apex of the roof: and for working a building by what is called natural ventilation such a height is excellent. Not that 40 feet is unworkable, for it is not, but a good height is in keeping with a bold design, and herein the architect and the ventilating engineer will be in agreement.

If it is intended to ventilate without mechanical aid, the height of the building is the first and chief point of importance, and it is much more necessary for natural ventilation than when mechanical aid is employed. But even where mechanical aid has been furnished it will be possible to do without during cold weather and dispense with the fan, if the building is high; and, as such a structure will afford so many thousand extra cubic feet of air by reason of the good height, it will be best that a church or hall shall be high although mechanical aid is to be supplied.

With regard to the ceiling, most modern buildings are now made without, and, for the sake of the extra cubic space, it is to be hoped that they will never come into fashion again. The first consideration is to make sure that the roof under the tiles is covered with felt which is joined air-tight alike between each width and between the last width and the wall-plate. Then it will be possible to keep the area of the outlets in the roof under command.

With regard to ventilators, if the building is long it is not wise to expect all the foul air to travel to the centre

and then through one opening. Such an opening would have to be large, and if the roof of the building were much higher than the roofs of the buildings around, the outlet would be subject to much suction, and it would be difficult to prevent alternating air currents being formed in windy weather. Two or three ventilators had better be used, and with a building 40 feet or more from the basement, if there is one, to the apex of the roof, the area of the inlets should be double that of the outlets for winter ventilation; and care should be taken to make provision for regulating the area of the outlets perfectly. During very cold weather, the extra ventilating power which is then at command, should be used up in forcing the air through the outlets under great pressure, and, therefore, at a high velocity. Under these circumstances the outlets should be closed considerably, and the ventilators had better be closed altogether, probably, when the temperature is below 32° F., unless it should happen that the felting of the roof is so air-tight that the interstitial cracks and spaces are not large enough for the outlet air —a state of things which the author has never met with in an unceiled building.

Another point of considerable weight bearing upon the ventilation of a building if it is to be done without mechanical aid, is the arrangement of the window openings for summer use. It is thought that a study of Fig. 6, p. 31, will throw some new light upon this subject. The window openings should be high up, and as many in number as it is possible to accommodate in the design. Window openings have hitherto been designed with a view to cause the air as it passes inwards to take a vertical direction, so that they may be used for winter ventilation. It is full time that the folly as well as the impossibility of ventilating by cold air was recognised, and this chapter is not complete until the point is reached where sufficient air is introduced through the floor to supply all that is required. Under these circumstances, all attempts

to furnish openings in the windows which shall throw air upward should be abandoned absolutely, and attention should now be given to make the window openings of the form best suited for summer ventilation. It is most advisable that the windows shall open so as to use the full aspirating power of the wind upon the air in the building. The movable pane falling inwards, shown on Fig. 10, p. 60, does not lend itself well to summer ventilation, for it neither favours the easy

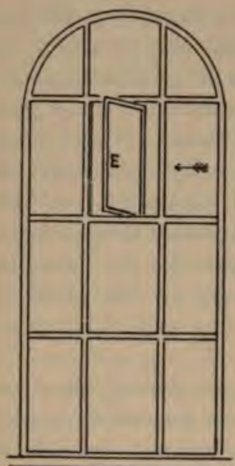


FIG. 24

FIG. 25

ingress nor the ready egress of air. Wind blowing along the front of a window would not aspirate powerfully on the opening. In order to effect this, hinged windows opening outwards, or window panes having pivots top and bottom, instead of the usual swinging panes pivoted longitudinally, are best. Alternate panes or windows when partly opened could be splayed to face the wind, which would then be caused to blow into the building, whilst the next pane could be

splayed in the opposite direction, the result being that the wind blowing against the edge, E., Fig. 25, would aspirate powerfully upon the air in the building. It should not be forgotten that wind blowing against E. will aspirate twice as much as if it blew along the flush front of the window, because the friction encountered will be so much less. Figs. 24 and 25 show these window openings. Windows are best made flush with the outer wall, or nearly so, the rebate being inside. For schools and halls it is also best for the windows to open outwards, as the action of the wind is so much more effective. Want of space prevents further reference, but enough has been said to show how important it is to give more attention to window openings of the form for summer ventilation. These openings can be used in place of the inward V. openings, Fig. 10, for winter use, and they are quite as effective, although not recommended for the purpose. The upward lift of the incoming air will be found to be much more imaginary than real, because the velocity has to be cut down, or the descending deluge would be intolerable.

The question of inlet air, its warming and introduction to the building, will be considered next. The author maintains that the best way of ventilating a building either with, or without mechanical aid, is by having a heating chamber underneath not less than 8 feet high, and preferably 10 feet if possible. With regard to the fresh cold inlet air, it must be taken from as pure a source as possible, and if it cannot be admitted into the building without being first subject to the effects of wind action, care must be taken to prevent the aspiration of the wind as much as possible at the points where the inlets start through the outer wall. These inlets should enter the heating chamber at the lowest point possible, and pass into the centre. Here a large body of hot water pipes should be laid, and the inlet air carefully distributed and heated by them. A row of small pipes should

be carried around the walls in the church or hall just above the floor to heat the air cooled by the walls and windows, and provision should also be made for warming the air in the lobbies, if there are any.

The inlets through the floor of the church or hall above should be covered over in such a way that the warm air can enter at the floor level and yet be prevented from shooting upwards. The opening of each inlet should be about 12 square inches in area, and 12 inches long, and two of these should be fixed in each pew, or six at least in every row of seats or chairs across the building. The inlets are best fixed under the seats or chairs.

With a heating chamber some 10 feet high to the top of the floor of the church or hall, there will be, as stated before, an increased ventilating power in the building. This increase should be used up in forcing the foul air through the outlets, and, whilst ample area should be afforded separately for spring and autumn use, the outlets for winter ventilation should be so under command that the cracks and interstices should not take much more than half the total volume of air coming in even when the temperature of the air outside is at 32° F. This statement is repeated here to show how necessary it is to expel the outlet air at a high velocity, so that the wind effects outside may not give rise to a down draught, or to intermittent air currents. By sending the inlet air through small apertures, and plenty of them, the velocity need not be great —the point is to leave enough ventilating power on the building to expel the outlet air at 10 feet per second if possible, and this can be done in very cold weather.

Where it is not practicable to have a mixing chamber underneath the building, the next best method of heating and ventilating is by hot water pipes under the aisles, in front of the communion rail, and round the walls of the building, so as to heat the cold air falling from windows, etc. The pipes under the aisles should be fed at frequent intervals by

fresh air ducts, and to ensure a more even distribution of the air along the pipes, each duct should have three ways ⅄ at the end joining the pipes. Above the fresh air way and underneath the pipes, sheets of perforated zinc having iron bound edges to keep them flat should be fixed, so as to make sure that no great rush of air can come up in one place. The grating over the pipes should be 2 feet wide, with apertures not less than 1½ inches square. It is most essential to avoid as much friction as possible, and the gratings must not be covered with matting or carpet. In the lobbies the air should be heated so that no draughts are felt in the aisles when the doors are momentarily opened.

The roof should be thoroughly felted, and all outlets placed under proper control. The windows and panes for summer ventilation should all open outwards as shown in Figs. 24 and 25.

Whether the pipes are laid under the aisles, or whether a heating and mixing chamber has been built under the church, as suggested, the architect will do well to provide a small window opening, say four square feet in area, as high as possible, and at the end of the church *furthest away from the prevailing winds*, so that the caretaker can get at it easily and open or shut it without the attention of the audience being directed to what is done. Wherever inlet air is being warmed, either before or as it enters a building, a sudden rush and pressure of the outer air through the doors as they are opened will have the effect of driving back the air from the inlets near the floor level. Any observant person will notice in a church heated with hot water pipes below the aisles and having air inlets entering the trough in which the pipes are fixed, that when the doors of the structure are opened for a few seconds the inlet air is backed, with the result that what remains around the pipes becomes strongly heated and is quickly driven inwards by the sudden rebound of the air through the inlets as soon as the doors

are shut again, whilst a moment or two later the incoming air appears to be much colder than it really is. The architect will do well to provide such a window opening as is described above, because this will enable the caretaker at the time the audience is entering the building to throw it more or less open, and relieve the internal pressure caused by the frequent opening of the doors. It may occur to some, perhaps, that if sufficient ventilators were provided, the caretaker could open these, and it would not be necessary for him to have a window for the purpose. It is not at all advisable, however, that the ventilators should be touched when the audience was assembling. These should be most carefully considered and regulated an hour before. If the ventilators were opened wide and forgotten, the church may be subjected to intermittent air currents all through the service. Furthermore, a window opening high up at the east end of the nave of a church would be most valuable for summer ventilation, especially where the prevailing winds blow from the west, south-west or north-west. Double doors are always provided in modern churches and most public buildings, and where air is warmed in quantity and admitted near the floor level, double doors are more necessary than ever.

CHAPTER IX.

INSTRUCTIONS FOR THE CARETAKER.

BEFORE proceeding to sum up the recommendations given in the preceding pages, and to set forth other duties devolving upon the caretaker, it may be well to point out some of the responsibilities resting upon the shoulders of the managers. It is a well-worn axiom that "neither men nor fools can work without tools," and it is incumbent upon the managers to see that all the appliances for ventilating and heating should be as workable as possible. If the caretaker has discovered from experience that the roof of the building is top heavy, and down draughts are pronounced in winter, due regard should be paid to the discovery; and, for the sake of the reduced coal and gas bills, it will be advisable to see that the outlet spaces are curtailed, even if the comfort of the audience does not demand it. If the caretaker has not sufficient knowledge to determine exactly what is wrong, and it can scarcely be expected that he has, it will pay to have expert advice upon the matter. In any case, if the ventilation of the building is upset by the outlet spaces being too large for winter use, the caretaker is not to blame if he cannot heat the walls so as to give comfort to those sitting near them, or keep the coal bill as low as may be expected of him. From experience, it has been found that a very large proportion of churches can only be partially heated for the Sunday services in cold weather, even if the fire is lighted on Saturday morning; and, in nine cases out

of ten, the reason is that there is no provision made for regulating the outlets, and keeping them under control. The caretaker is helpless under the circumstances.

One of the managers ought to understand the situation, and learn the nature of the appliances in use. It is to be feared that the general superintendence of the ventilation and heating is left entirely in the hands of the caretaker, and he has to go on blundering, or, what generally happens, do his best with very imperfect appliances. There ought to be some one in authority possessing sufficient physical knowledge to understand how things are going, and who by reason of that knowledge, is in a position to advise the caretaker as to what is best to be done. In other words, one of the managers should make a study of the ventilation and heating of the building in order that he may be able to instruct the caretaker. Reference is made principally to those managers who have to do with buildings where religious worship is held, and there is no doubt it is these which require most attention, because they are more in number, and used more frequently than other halls and some public buildings. Large concert halls and theatres ought to have some one with sufficient physical knowledge to look after the ventilating and heating, whose remuneration would naturally be greater than that usually given to the caretakers of churches.

One of the reasons which induced the author to recommend that a churchwarden or deacon, as the case may be, of a church should master the ventilating and heating, was because experience has shown that the greater number of those in control of the building act as would-be instructors, whilst, in the majority of instances, they know little or nothing about the matter. It is a good plan for the managers to select one of their number who is best qualified to act as superintendent of the ventilating and heating—the others leaving matters solely in his hands. This individual should make

himself thoroughly acquainted with the duties of his office, and inspect the inlets, outlets, etc., with the caretaker to see that all is in working order, and listen patiently to what he has to say, giving him all the help possible. Nothing is so discouraging to the caretaker as to have half a dozen or more in authority grumbling at him on account of the draughts, or the heat being insufficient, or too much. If *one* is left in command, this can be avoided, and any complaints made to a sidesman or seat steward should be passed on to the superintendent, who in turn would acquaint the caretaker if he thought fit. The author has met with many caretakers, some of whom were thinking men of high intelligence, who have simply given up using their wits on account of being made a target against which every seatholder thought he had a right to lodge his complaint. If some of the managers who pinned their faith to self-acting ventilators and other contrivances which have similar claims, could only understand how much thought and care and trouble were expended by the caretaker in striving to do his utmost under the circumstances, they would realise how misleading is the idea that with the best appliances ever furnished, all the caretaker has to do is to "Pull a lever when fresh air and perfect ventilation will come into play at once". There is no self-acting, nor will there ever be a self-acting system of ventilation. It will require all the sympathy and assistance of the manager, all the ability and knowledge he can command, and all the most approved appliances to enable the caretaker to keep the building in a satisfactory condition.

At the present time the caretakers are usually furnished with thermometers for determining the temperature inside the building, and they consult these to see how the heating is going on. Every superintendent should see that a good thermometer is provided for taking the temperature outside the building, and it would also improve matters considerably if he kept a short record of what was done to the inlets

and outlets each Sunday. This is rarely if ever attempted, and the consequence is that the caretaker is left to make a hit or miss attempt each time an audience assembles, and to open the inlets and outlets as he thinks best. If the temperature outside the building was taken first, and a note made showing how open or shut each ventilator should be at that temperature, then the ventilating of the building could be regulated methodically, and no longer left to chance as it is to-day. The ropes which close the valves of the ventilators should be attached to an arrangement which will admit of the ventilators being regulated with exactness and precision, and, with this provision and a thermometer for taking the outside temperature, the superintendent or the caretaker could soon make a table showing how the valves of the ventilators should stand *according to the temperature of the air outside.* If the superintendent compiled such a table of instructions, he might reasonably expect the caretaker to read the thermometer and regulate the ventilators accordingly.

THE CARETAKER.—His first thought should be directed to the exterior of the building, the influence of the winds, and of other buildings adjoining upon the ventilating and heating of that which he has to control. He should try to answer such questions as these. What is the position of the building? Does the main entrance face west or otherwise? From what quarter do the prevailing winds blow, and how will these strike the building? Is any portion of the structure sheltered from these winds, and if so what will be the results? At what angle to the ridge of the main roof do the prevailing winds blow, and how will they affect the ventilators on the roof? When the prevailing winds are blowing, will they cause reduced or increased pressure upon the air inlets and outlets? How will the window openings be affected by these winds? The wind blows from the east, from the west, *from the north*, or from the south, how will it affect the

ventilators in each case? How does the sun affect the building, and how can the extra heat upon one part be used to create a current of air inside the structure in the summer? What window openings will be best to use for ventilating by the assistance of the sun? How should the windows be opened so as to use the full power of the wind in summer? Is the building in an exposed position, upon cross roads, or otherwise? Can the position be made use of to assist ventilation either in summer or in winter? All these considerations are worthy of close study if the caretaker is going to master the subject as well as the work in hand. A thread of silk, a lighted match or taper, applied to the gratings or other openings will help greatly to reveal the action or suction of the wind, and enable the caretaker to answer some of the foregoing questions.

The next consideration is the condition of the inlets, if there are any, near the ground level. Are these clean and open? Are they all cold air inlets? Is it possible to so direct the air currents that the cold air inlets may be kept open? Can any air be let in through the cracks in the floor from underneath? Is there any other means of admitting the air near the ground level without causing cold feet? Does any ready and easy means of warming and admitting some fresh air into the building occur to you? For instance, is there a vestry with a fire, having a window through which air can come in, be partially warmed, and then passed into the assembly hall by leaving the door a little open? By trying to answer such questions as these, thought will be stimulated and some benefit will be sure to result in many of the buildings now so imperfectly ventilated.

If no thermometer has been supplied for taking the temperature of the air outside, the caretaker should lose no time in asking for one, or for one of the instruments which show the difference in pressure between the air inside and outside the building, and at the same time give the tempera-

ture of the air outside. He should know that the ventilating power of a building is to be measured by the difference in weight between the column of warm air inside and a column of cold air of the same height outside. That the warmer in reason he keeps the building in winter, the more air will get into it, and the more air will be expelled from it. If there is too much outlet area in the roof, cold air will come in, give rise to down draughts, and, at the same time, reduce the ventilating power of the building. By using his thermometer for outside temperatures, and closing the ventilators on the roof, he will soon find out at what temperature of the air outside there is any down draught experienced, and he will not be long in learning with certainty whether the ventilators can be opened at all without causing a down draught if the temperature outside is below 40° F. Should the caretaker find that there are down draughts and currents of air moving when all the valves are shut at 40° F., he will find also doubtless that there is much difficulty in warming his building at all under the circumstances. It will be best to keep the ventilators closed when the temperature is so low outside even whilst the audience is present, but he should call the attention of the managers to the fact, that something should be done to the roof in order to remedy the down draughts and intermittent air currents. As a general rule, in winter, the caretaker should open the ventilators as wide as possible without giving rise to down draughts, then close them to about three-quarters of the area so opened in order to make sure that the outlet air travels with good velocity. This is the best means of getting air through the building in *cold* weather, but the arrangement can only be carried out in winter if the area of the cracks and interstices has been properly adjusted. It is a practice generally recognised that the caretaker should open the ventilators as wide as possible, and the more movement there is of air the better the ventilation, providing there is no intolerable down draught. This is all very well for

summer ventilation, because every one knows that slight currents of air are most refreshing then, but it is in winter that air currents are deprecated, for perceptible movements of air in a building in the winter always mean intermittent air currents. The caretaker will act wisely, therefore, if he closes the ventilators in winter so as to prevent down draughts, and use up the ventilating power of the building in forcing air through the outlets under considerable velocity.

If provision has been made for warming air, however insufficient in volume, before it enters the building, every effort should be made to admit the *maximum possible*. Where inlets have been closed because too much air came up in one place, some perforated zinc sheets should be obtained from the managers, and an attempt made to more completely distribute the air. Simple shutters of wood or covers which shall rest against the air gratings and inlets in very cold weather so that the air coming in can be *entirely shut off* or nicely regulated, should be obtained. It would astonish most persons to see what an immense volume of air will get in through a small inlet when the temperature is below 35° F. and the air is very dry. This is why the thermometer for taking the temperature of the air outside is so strongly recommended, because a man reading it, and marking a low temperature, will soon learn how to adjust the inlets accordingly.

Some general remarks respecting the heating of the building come next in order. The caretaker naturally wishes to heat his building in the quickest time possible so that it will not be necessary for him to light the furnace on the Saturday morning in order to be ready for the Sunday morning service. If he succeeds in avoiding this, and lights the fire early on Sunday morning, it stands to reason that less coal will be consumed, and his duty will appear to be better done. If this is possible, he is lucky, and must have the control of a building whose top outlet space is either not exces-

sive or has been properly adjusted. But if the weather is cold, very few buildings can be sufficiently warmed by lighting the furnace on the Sunday morning. The chief value of having the top outlets capable of being closed almost perfectly, is the great saving of coal which can be effected in warming the building; and no caretaker can give satisfaction, or warm his building with certainty and economy, if the outlet spaces in the roof are excessive. Let it be assumed that the outlet spaces in the roof are excessive—what had the caretaker best do to heat his building? The heater is a hot air furnace. See that the cotton and woollen waste which settles inside the heater is cleaned out frequently, and that the gratings are clean also. This is very important. The caretaker should then go to the outside of the building, and find the grating through which fresh air is to get into the heater. Procure a cover which will close this *air-tight.* It may be argued that there is a lever connected with the apparatus to cut off the supply of fresh air. When the caretaker has had experience of the *immense volumes* of air that will pass a valve in cold weather, he will take sound advice, and close the air grating *on the outside.* When the building is ready for the audience, the cover should be lifted, and some fresh air admitted; but the quantity should never be so large that a lighted match or taper will not show a very appreciable movement in the current of cold air descending the grating. If there are any Tobin shafts, see that these are closed perfectly, and all inlets of whatever kind. As in the case of the air inlet to the heater, the most effective way to stop air entering a building is to close the grating perfectly on the *outside.*

Having closed all the inlets, attention should be given to the outlets. The ventilators should be closed, and all window openings as perfectly as possible. If the building is heated very slowly and insufficiently when the temperature is below 35° F. after these precautions have been taken, then the air leaking through cracks and interstices in the

roof and around the valves in the ventilators must be considerable, and the attention of the superintendent should be called to the matter so that expert advice may be obtained as to the best means of remedying such a state of things. Where the top outlets are excessive in area and not under control, and hot water pipes beneath the aisles are used for heating, having air inlets entering the troughs where the pipes are laid, care should be taken that the inlets, the pipes, and gratings, etc., should be cleaned frequently. All these inlets should be closed air-tight *outside* before the heating is commenced, and opened judiciously so as to allow the largest volume of warm air to enter, just before the audience assembles. As before, all outlets should be closed perfectly to heat the building.

In cold weather, the furnace is to be lit on Saturday, early, and a good fire maintained all night. Every effort should be made to heat the walls of the building to as near 60° F. as possible, but this can rarely be done in churches in very cold weather. The double doors in the lobbies should be kept shut during the heating, and ropes of felt having sand inside are useful to place against doors which have much air space under them. Where it is impossible to warm the air in the building sufficiently in consequence of the cold weather, the seat stewards should keep the double doors closed, and admit the audience, as far as possible, through one door at a time, but no time should be lost in having the outlet spaces in the roof attended to.

The caretakers of buildings where the outlets in the roof are less excessive, may always succeed in getting the temperature sufficiently high. They should, however, see that every inlet and outlet is carefully closed. If this can be done effectively, it will be best, notwithstanding, to light the furnace on Saturday afternoon, and keep it damped somewhat. If the fire is lit on Saturday night, or early on Sunday morning, the air may become warmed, but the walls

will not be properly heated; and whilst those in the centre of the building will find the temperature high enough, probably, those seated near windows and walls will be subjected to currents of cold air circulating and falling upon them in a very uncomfortable fashion. The heater will have unnecessary work to do during the time the audience is assembled, and the forced circulation of the air over hot plates of iron will lead to the formation of strong-smelling products from the oxidation of the organic matters in the breath, and the atmosphere in the building will be rendered very much more foul in consequence. On the other hand, if the furnace was lit some hours before, and the walls were heated to 60° F., cold currents from the walls would not be experienced, and the heater would have less work to perform. Where the outlets and inlets are alike under control, the temperature of the walls should be raised to 60° F., and a steady and prolonged heating is best under any circumstances. If the walls have been properly heated, it is best to lower the temperature of the air inside just before the audience assembles, and this can be done by opening the doors for a few minutes, and one or two windows on each side.

In spring and autumn when the temperature of the air outside is 50° F. or more, the caretaker is not unfrequently afraid to heat the air coming into the building for fear of getting it too hot. This difficulty can be obviated by making arrangements for the best control of the furnaces, and it is always advisable to heat the air a little, if possible, because the ventilation will be much improved. At these times, the inlets may be opened to their fullest capacity, and a gentle heat will remove the rawness from the air. A cold atmosphere inside is not only uncomfortable, but it becomes very foul also, and this is especially the case if the walls are cold and there is much moisture in the air before it enters. If the caretaker reads his thermometer for outside temperatures regularly, he will know by experience how to act.

With reference to the opening of windows, etc., for summer ventilation, a study of Fig. 6, p. 31, will enable the caretaker to see what is best to be done. He should know from what quarter the wind is blowing before the window openings are adjusted, and should be sure as to the effects of the wind. After a little thought and practice this will not be found difficult, nor is the mastery of the subject beyond the grasp of the average caretaker. The point to remember is that moving air always draws other air in the same direction. If the wind blows parallel to the side of a building, it will draw air out of any opening which is flush with it. A window which opens outwards and is splayed towards the wind, can be made to force air into a building. Wind blowing over a roof, draws air from the farther side, but any openings on the near side would be powerful inlets. By carefully noting and weighing these facts, the caretaker, having ascertained the direction of the wind, can make use of them to advantage for summer ventilation. The foregoing remarks apply so nearly to public halls as well as churches that no separate mention need be made of them.

Hitherto attention has been directed chiefly to churches and places of worship; a few hints on the ventilation of schools will be given next. Each classroom is a small hall warmed and ventilated by itself, unless it happens that the outlets of all the classrooms are connected with one or more air shafts. If fires are used in the classrooms, and foul air shafts carried up alongside the flue, and there is no other means of heating, the caretaker can do little except to open the windows so as to let as much fresh air in as is consistent with reasonable comfort to the children, before they assemble; and to open the doors and windows wide, the very moment the children leave the building. If the building is heated by hot water or steam, and sufficient warm air is admitted, it will be easy to get rid of the foul air if there is a separate outlet for each classroom; and if the outlets

pass into one or more shafts, it ought not to be difficult to get rid of the foul air once the area of the outlets was adjusted. Where fans are used to expel the foul air, it is still more easy to get rid of it provided warm air is admitted in good volume. Even then, however, the outlets want careful adjustment, and it is too much to expect the caretaker to do this, because it is a matter of nicety and difficulty even to experts.

Where the caretaker has several rooms, halls, or classrooms to superintend, and the outlets lead to one or more shafts, most careful attention should be given to prevent a rush of air into the shaft through one or more of the outlets. Let us suppose there are six classrooms having outlets leading into the same shaft. Four of the classrooms are occupied by large classes and require the outlets to work to their fullest power. The two other classrooms are empty, and the caretaker has left the windows open with that best of intention—to sweeten them. For want of proper adjustment, the outlets in all the classrooms are too large, but when the six classrooms are in use they draw off about equal volumes of air. When, however, one or more classrooms is empty, and *the pressure of the outer air gets freely in because the windows are opened, four times as much air goes through the outlet as was the case when all the classrooms were occupied and all the windows were shut.* Furthermore, it is winter, and the air outside very cold, the result being that such a large volume of frigid air gets into the outlet shaft through the openings in the unoccupied classrooms that the ventilating power in the outlet shaft is reduced to an almost unworkable extent. The unused classroom with its open window may, therefore, do immense mischief to the general ventilation. Such a state of things requires the most careful consideration, and the caretaker will do well to regard it seriously. There are two alternatives. (1) The outlet in the classroom should be capable of being closed, and closed accordingly. This would

be best, but the caretaker *must open it* before the room is used. (2) The windows should all be closed alike in winter when the children are in school, no matter how many classrooms are used. Where natural ventilation is relied upon, and the area of the air shaft is ample, the best plan is to arrange the windows, doors and outlets so that the pull shall be alike in each classroom. If some of the outlets are closed, the danger is that down draughts may occur, because the outer air falls down the shaft, and these must be avoided. It is impossible to lay too much stress upon the importance of studying this question of outlet action where a number enter one central shaft.

Where hot water or steam is used for heating, it will be advisable in cold weather to keep the fires well tended so that as much warm air as possible can be obtained; or, in case the windows are the only inlets, that the cold air may be warmed in the best way to secure the comfort of the children. It may happen that the atmosphere in the assembly hall in the centre of the school buildings is kept under much tension through the classrooms getting all the air they can from underneath, and around the doors leading to the hall. It is not easy to ventilate such a large room in the centre of a block of classrooms to the best advantage under the circumstances, and where one or more classroom[1] is unused, the hall can receive much air from it, and, by using the passages as warm air channels, the doors leading thereto may be used as further inlets for fresh air. A wax match, or small taper will enable the caretaker to follow the air currents and learn their direction in order to understand and master some of these difficulties; but it is only fair to say that many caretakers work their buildings with great skill, whilst the managers ought to have further expert advice so that the

[1] If the classroom is used to feed the hall, the *outlet* had better be closed, especially if it goes into a central shaft, otherwise some foul air may be aspirated out of it.

air supply might be better arranged. The atmosphere in some of the halls which are used for teaching at the same time that the classrooms are occupied, in consequence of the school being overcrowded, is usually very foul indeed.

With regard to town halls, council chambers, and other large rooms and halls, these will be subjected to the aspiration and wind effects mentioned in Chapter II., and the action of winds upon Tobin shafts or other inlets and outlets should be carefully studied so as to become acquainted with the effects which will be experienced according to the direction of the wind. Where a complete apparatus for heating and ventilating has been arranged, and where a fan is used to drive air into the building, the feeding of the rooms with extra air, such as council chambers, etc., just when it is wanted, will be the duty of the caretaker. If the general direction of the air currents can be determined, and information obtained which will help him in the best distribution of the warmed air in winter, and the cooled air in summer, so much the better for those in the building, but by reason of the number of passages, and the manner in which the air currents are diverted according to the temperature of the air outside and the direction of the winds, the whole subject should be carefully studied and worked out by an expert first, so that the ventilation can be better handled by the caretaker. Warm air currents do not travel always in the direction required, and when air is cooled in summer and autumn, special knowledge is necessary so as to distribute it aright. At a recent meeting of the British Association, a soirée was given in the City buildings. In the main hall where a concert was in progress the atmosphere was positively stifling, whilst in the corridors so much washed and cooled air was circulating that it was dangerous to persons coming out of the hall to stand there. These City buildings were supposed to have one of the best and most effective fan-aided systems of ventilation, but for want of proper distribution the cooled air

was lacking where it was most needed, and, on that occasion, at any rate, the system was a failure. Where a number of rooms and passages are intended to be heated and ventilated from one source, situated perhaps in the basement at the end of the building, it is not fair to expect the caretaker to know how to distribute the air aright unless proper provision has been made at first. Nor is it likely, either, that the driver of the engine working the fan should possess the requisite knowledge. Indeed, unless an expert has an opportunity of examining and testing the air currents in actual operation, and to form a sound opinion as to how they will be affected by the winds, it will puzzle him not a little to arrange and set out the distribution of the air so that the different rooms and halls shall get their proper share.

The same remarks apply to hospitals, and other buildings in which several rooms and wards occur. It is quite possible to ventilate these from one central source, and without particularising any one, there are many such buildings where a more or less elaborate system of heating and ventilating has been carried out. Where provision has been made for introducing large volumes of air more or less purified and warmed, the system has not always worked well, and in not a few instances what appeared on paper so feasible has proved most disappointing in working. There are some arrangements so good in general outline, that with a little care and alteration of the area of the inlets and outlets, the whole plan might be made to give admirable results, but it is to be feared that the caretaker would not be much benefited by referring to any of these instances in detail. In buildings of this kind, where mechanical appliances are used to ventilate, or where furnace action is employed, the caretaker has no lot in the matter, the engine driver or stoker doing what little is done. On the other hand, the opening of certain windows and ventilators by those inside the building, not unfrequently results in upsetting the ventilation of

the adjoining rooms or wards. Some one ought to be in charge of the ventilation, and alone responsible for it, who should study and master the effects of wind action, and the difficulties attached to the proper control of the inlets, outlets, and other arrangements. Unless this is done, the best planned and furnished system may become inoperative and unworkable, and what might, with proper supervision and a little adjustment, prove perfectly successful, will be condemned as useless and wrong in principle.

INDEX.

THE ABERDEEN UNIVERSITY PRESS LIMITED.

A SELECT LIST OF BOOKS

IN

NATURAL AND PHYSICAL SCIENCE, MATHEMATICS AND TECHNOLOGY

PUBLISHED BY

Messrs. LONGMANS, GREEN, & CO.

LONDON: 39 PATERNOSTER ROW, E.C.

NEW YORK: 91 & 93 FIFTH AVENUE.

BOMBAY: 32 HORNBY ROAD.

CHEMISTRY.

ARRHENIUS.—A TEXT-BOOK OF ELECTROCHEMISTRY. By SVANTE ARRHENIUS, Professor at the University of Stockholm. Translated from the German Edition by JOHN MCCRAE, Ph.D. With 58 Illustrations. 8vo., 9*s.* 6*d.* net.

CROOKES.—SELECT METHODS IN CHEMICAL ANALYSIS, chiefly Inorganic. By Sir WILLIAM CROOKES, F.R.S., etc. Third Edition, Rewritten and Enlarged. With 67 Woodcuts. 8vo., 21*s.* net.

FURNEAUX.—ELEMENTARY CHEMISTRY, Inorganic and Organic. By W. FURNEAUX, F.R.G.S., Lecturer on Chemistry, London School Board. With 65 Illustrations and 155 Experiments. Crown 8vo., 2*s.* 6*d.*

GARRETT AND HARDEN.—AN ELEMENTARY COURSE OF PRACTICAL ORGANIC CHEMISTRY. By F. C. GARRETT, M.Sc. (Vict. et Dunelm.), Assistant Lecturer and Demonstrator in Chemistry, the Durham College of Science, Newcastle-on-Tyne; and ARTHUR HARDEN, M.Sc. (Vict.), Ph.D., Assistant Lecturer and Demonstrator in Chemistry, the Owens College, Manchester. With 14 Illustrations. Crown 8vo., 2*s.*

JAGO.—Works by W. JAGO, F.C.S., F.I.C.

INORGANIC CHEMISTRY, THEORETICAL AND PRACTICAL. With an Introduction to the Principles of Chemical Analysis, Inorganic and Organic. With 63 Woodcuts and numerous Questions and Exercises. Fcp. 8vo., 2*s.* 6*d.*

AN INTRODUCTION TO PRACTICAL INORGANIC CHEMISTRY. Crown 8vo., 1*s.* 6*d.*

INORGANIC CHEMISTRY, THEORETICAL AND PRACTICAL. A Manual for Students in Advanced Classes of the Science and Art Department. With Plate of Spectra and 78 Woodcuts. Crown 8vo., 4*s.* 6*d.*

MELLOR.—HIGHER MATHEMATICS FOR STUDENTS OF CHEMISTRY AND PHYSICS. With Special Reference to Practical Work. By J. W. MELLOR, D.Sc., late Senior Scholar, and 1851 Exhibition Scholar, New Zealand University; Research Fellow, the Owens College, Manchester. With 142 Diagrams. 8vo., 12*s.* 6*d.* net.

MENDELÉEFF.—THE PRINCIPLES OF CHEMISTRY. By D. MENDELÉEFF. Translated from the Russian (Sixth Edition) by GEORGE KAMENSKY, A.R.S.M., of the Imperial Mint, St. Petersburg; and Edited by T. A. LAWSON, B.Sc., Ph.D., Fellow of the Institute of Chemistry. With 96 Diagrams and Illustrations. 2 vols. 8vo., 36*s.*

MEYER.—OUTLINES OF THEORETICAL CHEMISTRY. By LOTHAR MEYER, Professor of Chemistry in the University of Tübingen. Translated by Professors P. PHILLIPS BEDSON, D.Sc., and W. CARLETON WILLIAMS, B.Sc. 8vo., 9*s.*

MILLER.—INTRODUCTION TO THE STUDY OF INORGANIC CHEMISTRY. By W. ALLEN MILLER, M.D., LL.D. With 71 Illustrations. Fcp. 8vo., 3*s.* 6*d.*

CHEMISTRY—*Continued.*

MUIR.—A COURSE OF PRACTICAL CHEMISTRY. By M. M. P. MUIR, M.A., Fellow and Prælector in Chemistry of Gonville and Caius College, Cambridge. (3 Parts.)

Part I. Elementary. Crown 8vo., 4*s.* 6*d.*

Part II. Intermediate. Crown 8vo., 4*s.* 6*d.*

Part III. [*In preparation.*

NEWTH.—Works by G. S. NEWTH, F.I.C. F.C.S., Demonstrator in the Royal College of Science, London.

CHEMICAL LECTURE EXPERIMENTS. With 230 Illustrations. Crown 8vo., 6*s.*

CHEMICAL ANALYSIS, QUANTITATIVE AND QUALITATIVE. With 100 Illustrations. Crown 8vo., 6*s.* 6*d.*

A TEXT-BOOK OF INORGANIC CHEMISTRY. With 155 Illustrations. Crown 8vo., 6*s.* 6*d.*

ELEMENTARY PRACTICAL CHEMISTRY. With 108 Illustrations and 254 Experiments. Crown 8vo., 2*s.* 6*d.*

OSTWALD.—SOLUTIONS. By W. OSTWALD, Professor of Chemistry in the University of Leipzig. Being the Fourth Book, with some additions, of the Second Edition of Oswald's 'Lehrbuch der allgemeinen Chemie'. Translated by M. M. PATTISON MUIR, Fellow and Prælector in Chemistry of Gonville and Caius College, Cambridge. 8vo., 10*s.* 6*d.*

PERKIN.—QUALITATIVE CHEMICAL ANALYSIS (ORGANIC AND INORGANIC). By F. MOLLWO PERKIN, Ph.D., Head of the Chemistry Department, Borough Polytechnic Institute, London. With 9 Illustrations and Spectrum Plate. 8vo., 3*s.* 6*d.*

REYNOLDS.—EXPERIMENTAL CHEMISTRY FOR JUNIOR STUDENTS. By J. EMERSON REYNOLDS, M.D., F.R.S., Professor of Chemistry, University of Dublin. Fcp. 8vo., with numerous Woodcuts.

Part I. Introductory. Fcp. 8vo., 1*s.* 6*d.*

Part II. Non-Metals, with an Appendix on Systematic Testing for Acids. Fcp. 8vo., 2*s.* 6*d.*

Part III. Metals, and Allied Bodies. Fcp. 8vo., 3*s.* 6*d.*

Part IV. Carbon Compounds. Fcp. 8vo., 4*s.*

SHENSTONE.—Works by W. A. SHENSTONE, F.R.S., Lecturer on Chemistry in Clifton College.

THE METHODS OF GLASS-BLOWING AND OF WORKING SILICA IN THE OXY-GAS FLAME. For the Use of Physical and Chemical Students. With 43 Illustrations. Crown 8vo., 2*s.* 6*d.*

A PRACTICAL INTRODUCTION TO CHEMISTRY. Intended to give a Practical acquaintance with the Elementary Facts and Principles of Chemistry. With 25 Illustrations. Crown 8vo., 2*s.*

CHEMISTRY—*Continued.*

SMITH AND HALL.—THE TEACHING OF CHEMISTRY AND PHYSICS IN THE SECONDARY SCHOOL. By ALEXANDER SMITH, B.Sc., Ph.D., Associate Professor of Chemistry in the University of Chicago, and EDWIN H. HALL, Ph.D., Professor of Physics in Harvard University. With 21 Woodcuts, Bibliographies, and Index. Crown 8vo., 6*s.* net.

THORNTON AND PEARSON.—NOTES ON VOLUMETRIC ANALYSIS. By ARTHUR THORNTON, M.A., and MARCHANT PEARSON, B.A., Assistant Science Master, Bradford Grammar School. Medium 8vo., 2*s.*

THORPE.—Works by T. E. THORPE, C.B., D.Sc. (Vict.), Ph.D., F.R.S., Principal of the Government Laboratory, London. Assisted by Eminent Contributors.

A DICTIONARY OF APPLIED CHEMISTRY. 3 vols. 8vo. Vols. I. and II., 42*s.* each. Vol. III., 63*s.*

QUANTITATIVE CHEMICAL ANALYSIS. With 88 Woodcuts. Fcp. 8vo., 4*s.* 6*d.*

THORPE AND MUIR.—QUALITATIVE CHEMICAL ANALYSIS AND LABORATORY PRACTICE. By T. E. THORPE, C.B., Ph.D., D.Sc., F.R.S., and M. M. PATTISON MUIR, M.A. With Plate of Spectra and 57 Illustrations. Fcp. 8vo., 3*s.* 6*d.*

TILDEN.—Works by WILLIAM A. TILDEN, D.Sc. London, F.R.S., Professor of Chemistry in the Royal College of Science, South Kensington.

A SHORT HISTORY OF THE PROGRESS OF SCIENTIFIC CHEMISTRY IN OUR OWN TIMES. Crown 8vo., 5*s.* net.

INTRODUCTION TO THE STUDY OF CHEMICAL PHILOSOPHY. The Principles of Theoretical and Systematic Chemistry. With 5 Illustrations. Fcp. 8vo., 5*s.* With ANSWERS to Problems. Fcp. 8vo., 5*s.* 6*d.*

PRACTICAL CHEMISTRY. The principles of Qualitative Analysis. Fcp. 8vo., 1*s.* 6*d.*

WATTS' DICTIONARY OF CHEMISTRY. Revised and entirely Rewritten by H. FORSTER MORLEY, M.A., D.Sc., Fellow of, and lately Assistant Professor of Chemistry in, University College, London; and M. M. PATTISON MUIR, M.A., F.R.S.E., Fellow, and Prælector in Chemistry, of Gonville and Caius College, Cambridge. Assisted by Eminent Contributors. 4 vols. 8vo., £5 net.

WHITELEY.—Works by R. LLOYD WHITELEY, F.I.C., Principal of the Municipal Science School, West Bromwich.

CHEMICAL CALCULATIONS. With Explanatory Notes, Problems and Answers, specially adapted for use in Colleges and Science Schools. With a Preface by Professor F. CLOWES, D.Sc. (Lond.), F.I.C. Crown 8vo., 2*s.*

ORGANIC CHEMISTRY: the Fatty Compounds. With 45 Illustrations. Crown 8vo., 3*s.* 6*d*

PHYSICS, ETC.

BIDGOOD.—ELEMENTARY PHYSICS AND CHEMISTRY FOR THE USE OF SCHOOLS. (In Three Books.) By JOHN BIDGOOD, B.Sc., Headmaster of the Gateshead School of Science.

Book I. Elementary Physics. With 120 Illustrations. Crown 8vo., 1*s.* 6*d.*

Book II. Physics and Chemistry. With 122 Illustrations. Crown 8vo., 1*s.* 6*d.*

BOSE.—RESPONSE IN THE LIVING AND NON-LIVING. By JAGADIS CHUNDER BOSE, M.A. (Cantab.), D.Sc. (Lond.), Professor, Presidency College, Calcutta. With 117 Illustrations. 8vo., 10*s.* 6*d.*

*** *This volume describes experimental investigations on animal, vegetable and inorganic substances regarding their response to stimulus. These researches show that the effects of fatigue, stimulants, depressants and poisons are alike in the organic and inorganic, and demonstrate that the response phenomena in the 'living' have been foreshadowed in the 'non-living'.*

GANOT.—Works by PROFESSOR GANOT. Translated and Edited by E. ATKINSON, Ph.D., F.C.S., and A. W. REINOLD, M.A., F.R.S.

ELEMENTARY TREATISE ON PHYSICS, Experimental and Applied. With 9 Coloured Plates and Maps, and 1048 Woodcuts, and Appendix of Problems and Examples with Answers. Crown 8vo., 15*s.*

NATURAL PHILOSOPHY FOR GENERAL READERS AND YOUNG PEOPLE. With 7 Plates, 632 Woodcuts, and an Appendix of Questions. Crown 8vo. 7*s.* 6*d.*

GLAZEBROOK AND SHAW.—PRACTICAL PHYSICS. By R. T. GLAZEBROOK, M.A., F.R.S., and W. N. SHAW, M.A. With 134 Illustrations. Fcp. 8vo., 7*s.* 6*d.*

GUTHRIE.—MOLECULAR PHYSICS AND SOUND. By F. GUTHRIE, Ph.D. With 91 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

HELMHOLTZ.—POPULAR LECTURES ON SCIENTIFIC SUBJECTS. By HERMANN VON HELMHOLTZ. Translated by E. ATKINSON, Ph.D., F.C.S., formerly Professor of Experimental Science, Staff College. With 68 Illustrations. 2 vols., crown 8vo., 3*s.* 6*d.* each.

HENDERSON.—ELEMENTARY PHYSICS. By JOHN HENDERSON, D.Sc. (Edin.), A.I.E.E., Physics Department, Borough Road Polytechnic. Crown 8vo., 2*s.* 6*d.*

MACLEAN.—EXERCISES IN NATURAL PHILOSOPHY. By MAGNUS MACLEAN, D.Sc., Professor of Electrical Engineering at the Glasgow and West of Scotland Technical College. Crown 8vo., 4*s.* 6*d.*

MEYER.—THE KINETIC THEORY OF GASES. Elementary Treatise, with Mathematical Appendices. By Dr. OSKAR EMIL MEYER, Professor of Physics at the University of Breslau. Second Revised Edition. Translated by ROBERT E. BAYNES, M.A., Student of Christ Church, Oxford, and Dr. Lee's Reader in Physics. 8vo., 15*s.* net.

VAN 'T HOFF.—THE ARRANGEMENT OF ATOMS IN SPACE. By J. H. VAN T'HOFF. Second, Revised, and Enlarged Edition. With a Preface by JOHANNES WISLICENUS, Professor of Chemistry at the University of Leipzig; and an Appendix 'Stereo-chemistry among Inorganic Substances,' by ALFRED WERNER, Professor of Chemistry at the University of Zürich. Translated and Edited by ARNOLD EILOART. Crown 8vo., 6s. 6d.

PHYSICS, ETC.—*Continued.*

WATSON.—Works by W. WATSON, A.R.C.S., F.R.S., D.Sc., Assistant Professor of Physics at the Royal College of Science, London.

ELEMENTARY PRACTICAL PHYSICS: a Laboratory Manual for Use in Organised Science Schools. With 120 Illustrations and 193 Exercises. Crown 8vo., 2*s.* 6*d.*

A TEXT-BOOK OF PHYSICS. With 568 Diagrams and Illustrations, and a Collection of Examples and Questions, with Answers. Large crown 8vo., 10*s.* 6*d.*

WORTHINGTON.—A FIRST COURSE OF PHYSICAL LABORATORY PRACTICE. Containing 264 Experiments. By A. M. WORTHINGTON, M.A., F.R.S. With Illustrations. Crown 8vo., 4*s.* 6*d.*

WRIGHT.—ELEMENTARY PHYSICS. By MARK R. WRIGHT, M.A., Professor of Normal Education, Durham College of Science. With 242 Illustrations. Crown 8vo., 2*s.* 6*d.*

MECHANICS, DYNAMICS, STATICS, HYDROSTATICS, ETC.

BALL.—A CLASS-BOOK OF MECHANICS. By Sir R. S. BALL, LL.D. 89 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

GOODEVE.—Works by T. M. GOODEVE, M.A., formerly Professor of Mechanics at the Normal School of Science, and the Royal School of Mines.

THE ELEMENTS OF MECHANISM. With 357 Illustrations. Crown 8vo., 6*s.*

PRINCIPLES OF MECHANICS. With 253 Illustrations and numerous Examples. Crown 8vo., 6*s.*

A MANUAL OF MECHANICS: an Elementary Text-Book for Students of Applied Mechanics. With 138 Illustrations and Diagrams and 188 Examples taken from the Science Department Examination Papers, with Answers. Fcp. 8vo., 2*s.* 6*d.*

GOODMAN.—MECHANICS APPLIED TO ENGINEERING By JOHN GOODMAN, Wh.Sch., A.M.I.C.E., M.I.M.E., Professor of Engineering in the Yorkshire College, Leeds (Victoria University). With 620 Illustrations and numerous examples. Crown 8vo., 7*s.* 6*d.* net.

GRIEVE.—LESSONS IN ELEMENTARY MECHANICS. By W. H. GRIEVE, late Engineer, R.N., Science Demonstrator for the London School Board, etc.

Stage 1. With 165 Illustrations and a large number of Examples. Fcp. 8vo., 1*s.* 6*d.*

Stage 2. With 122 Illustrations. Fcp. 8vo., 1*s.* 6*d.*

Stage 3. With 103 Illustrations. Fcp. 8vo., 1*s.* 6d.

MECHANICS, DYNAMICS, STATICS, HYDROSTATICS, ETC.—*Continued.*

MAGNUS.—Works by SIR PHILIP MAGNUS, B.Sc., B.A.

LESSONS IN ELEMENTARY MECHANICS. Introductory to the study of Physical Science. Designed for the Use of Schools, and of Candidates for the London Matriculation and other Examinations. With numerous Exercises, Examples, Examination Questions, and Solutions, etc., from 1870-1895. With Answers, and 131 Woodcuts. Fcp. 8vo., 3*s*. 6*d*.

Key for the use of Teachers only, price 5*s*. 3½*d*.

HYDROSTATICS AND PNEUMATICS. Fcp. 8vo., 1*s*. 6*d*.; or, with Answers, 2*s*. The Worked Solutions of the Problems, 2*s*.

PULLEN.—MECHANICS: Theoretical, Applied, and Experimental. By W. W. F. PULLEN, WH. SC. M.I.M.E., A.M.I.C.E. With 318 Diagrams and numerous Examples. Crown 8vo., 4*s*. 6*d*.

ROBINSON.—ELEMENTS OF DYNAMICS (Kinetics and Statics). With numerous Exercises. A Text-book for Junior Students. By the Rev. J. L. ROBINSON, M.A. Crown 8vo., 6*s*.

SMITH.—Works by J. HAMBLIN SMITH, M.A.

ELEMENTARY STATICS. Crown 8vo., 3*s*.

ELEMENTARY HYDROSTATICS. Crown 8vo., 3*s*.

KEY TO STATICS AND HYDROSTATICS. Crown 8vo., 6*s*.

TARLETON.—AN INTRODUCTION TO THE MATHEMATICAL THEORY OF ATTRACTION. By FRANCIS A. TARLETON, LL.D., Sc.D., Fellow of Trinity College, and Professor of Natural Philosophy in the University of Dublin. Crown 8vo., 10*s*. 6*d*.

TAYLOR.—Works by J. E. TAYLOR, M.A., B.Sc. (Lond.).

THEORETICAL MECHANICS, including Hydrostatics and Pneumatics. With 175 Diagrams and Illustrations, and 522 Examination Questions and Answers. Crown 8vo., 2*s*. 6*d*.

THEORETICAL MECHANICS—SOLIDS. With 163 Illustrations, 120 Worked Examples and over 500 Examples from Examination Papers, etc. Crown 8vo., 2*s*. 6*d*.

THEORETICAL MECHANICS.—FLUIDS. With 122 Illustrations, numerous Worked Examples, and about 500 Examples from Examination Papers, etc. Crown 8vo., 2*s*. 6*d*.

THORNTON.—THEORETICAL MECHANICS—SOLIDS. Including Kinematics, Statics and Kinetics. By ARTHUR THORNTON, M.A., F.R.A.S. With 200 Illustrations, 130 Worked Examples, and over 900 Examples from Examination Papers, etc. Crown 8vo., 4*s*. 6*d*.

THE CALCULUS, LOGARITHMS, ETC.

BARKER.—GRAPHICAL CALCULUS. By ARTHUR H. BARKER, B.A., B.Sc. With an Introduction by JOHN GOODMAN, A.M.I.C.E. With 61 Diagrams. Crown 8vo., 4*s.* 6*d.*

MURRAY.—AN INTRODUCTORY COURSE IN DIFFERENTIAL EQUATIONS. By DANIEL ALEXANDER MURRAY, Ph.D. Crown 8vo., 4*s.* 6*d.*

TATE.—PRINCIPLES OF THE DIFFERENTIAL AND INTEGRAL CALCULUS. Applied to the Solution of Useful Problems in Mathematics and Mechanics. By THOMAS TATE. 12mo, 4*s.* 6*d.*

TAYLOR.—Works by F. GLANVILLE TAYLOR.

AN INTRODUCTION TO THE DIFFERENTIAL AND INTEGRAL CALCULUS AND DIFFERENTIAL EQUATIONS. Crown 8vo., 9*s.*

AN INTRODUCTION TO THE PRACTICAL USE OF LOGARITHMS, WITH EXAMPLES IN MENSURATION. With Answers to Exercises. Crown 8vo., 1*s.* 6*d.*

WILLIAMSON.—Works by BENJAMIN WILLIAMSON, D.Sc.

AN ELEMENTARY TREATISE ON THE DIFFERENTIAL CALCULUS; containing the Theory of Plane Curves with numerous Examples. Crown 8vo., 10*s.* 6*d.*

AN ELEMENTARY TREATISE ON THE INTEGRAL CALCULUS; containing Applications to Plane Curves and Surfaces, and also a Chapter on the Calculus of Variations, with numerous Examples. Crown 8vo., 10*s.* 6*d.*

GEOMETRY AND EUCLID.

*** *For other Works, see Longmans & Co.'s Catalogue of Educational and School Books.*

ALLMAN.—GREEK GEOMETRY FROM THALES TO EUCLID. By G. J. ALLMAN. 8vo., 10*s.* 6*d.*

CASEY.—Works by JOHN CASEY, LL.D., F.R.S.

THE ELEMENTS OF EUCLID, BOOKS I.-VI. and Propositions, I.-XXI. of Book XI., and an Appendix of the Cylinder, Sphere, Cone, etc. With Copious Annotations and numerous Exercises. Fcp. 8vo., 4*s.* 6*d.* KEY to Exercises. Fcp. 8vo., 6*s.*

A SEQUEL TO THE ELEMENTS OF EUCLID. Part I. Books I.-VI. With numerous Examples. Fcp. 8vo., 3*s.* 6*d.*

A TREATISE ON THE ANALYTICAL GEOMETRY OF THE POINT, LINE, CIRCLE AND CONIC SECTIONS. Containing an Account of its most recent Extension. Crown 8vo., 12*s.*

GEOMETRY AND EUCLID—*Continued.*

HAMILTON.—ELEMENTS OF QUATERNIONS. By the late Sir WILLIAM ROWAN HAMILTON, LL.D., M.R.I.A. Edited by CHARLES JASPER JOLY, M.A., Fellow of Trinity College, Dublin. 2 vols. 4to. 21*s.* net each.

HIME.—THE OUTLINES OF QUATERNIONS. By Lieut.-Colonel H. W. L. HIME, late Royal Artillery. Crown 8vo., 10*s.*

LOW.—TEXT-BOOK ON PRACTICAL, SOLID, AND DESCRIPTIVE GEOMETRY. By DAVID ALLAN LOW, Professor of Engineering, East London Technical College. Crown 8vo.

Part I. With 114 Figures, 2*s.*

Part II. With 64 Figures, 3*s.*

MORRIS.—Works by I. HAMMOND MORRIS.

PRACTICAL PLANE AND SOLID GEOMETRY, including Graphic Arithmetic fully Illustrated with Drawings prepared specially by the Author. Crown 8vo., 2*s.* 6*d.*

GEOMETRICAL DRAWING FOR ART STUDENTS. Embracing Plane Geometry and its Applications, the Use of Scales, and the Plans and Elevations of Solids as required in Section I. of Science Subjects. Crown 8vo., 2*s.*

SMITH.—ELEMENTS OF GEOMETRY. By J. HAMBLIN SMITH, M.A. Containing Books 1 to 6, and portions of Books 11 and 12, of Euclid, with Exercises and Notes. Crown 8vo., 3*s.* 6*d.* KEY, crown 8vo., 8s. 6*d.*

Books 1 and 2, limp cloth, 1*s.* 6*d.*, may be had separately.

SPOONER.—THE ELEMENTS OF GEOMETRICAL DRAWING: an Elementary Text-book on Practical Plane Geometry, including an Introduction to Solid Geometry. Written to include the requirements of the Syllabus of the Board of Education in Geometrical Drawing and for the use of Students preparing for the Military Entrance Examinations. By HENRY J. SPOONER, C.E., M.Inst.M.E.; Director of the Polytechnic School of Engineering, etc. Crown 8vo., 3*s.* 6*d.*

WATSON.—ELEMENTS OF PLANE AND SOLID GEOMETRY. By H. W. WATSON, M.A. Fcp. 8vo., 3*s.* 6*d.*

WILSON.—GEOMETRICAL DRAWING. For the use of Candidates for Army Examinations, and as an Introduction to Mechanical Drawing. By W. N. WILSON, M.A. Parts I. and II. Crown 8vo., 4*s.* 6*d.* each.

WINTER.—ELEMENTARY GEOMETRICAL DRAWING. By S. H. WINTER.

Part I. Including Practical Plane Geometry, the Construction of Scales, the Use of the Sector, the Marquois Scales, and the Protractor. With 3 Plates and 1000 Exercises and Examination Papers. Post 8vo., 5*s.*

TRIGONOMETRY.

CASEY.—A TREATISE ON ELEMENTARY TRIGONOMETRY. By JOHN CASEY, LL.D., F.R.S., late Fellow of the Royal University of Ireland. With numerous Examples and Questions for Examination. 12mo, 3*s*.

CLARKE.—PLANE TRIGONOMETRY. Containing the more advanced Propositions, Solution of Problems and a complete Summary of Formulæ, Bookwork, etc., together with recent Examination Papers for the Army, Woolwich, etc. With Answers. By the Rev. A. DAWSON CLARKE, M.A., St. John's College, Cambridge. Crown 8vo., 5*s*.

GOODWIN.—Works by H. B. GOODWIN, M.A.

PLANE AND SPHERICAL TRIGONOMETRY. In Three Parts, comprising those portions of the subjects, theoretical and practical, which are required in the Final Examination for Rank of Lieutenant at Greenwich. 8vo., 8*s*. 6*d*.

ELEMENTARY PLANE TRIGONOMETRY. With numerous Examples and Examination Papers set at the Royal Naval College in recent years. With Answers. 8vo., 5*s*.

JONES.—THE BEGINNINGS OF TRIGONOMETRY. By A. CLEMENT JONES, M.A., Ph.D., late Open Scholar and Senior Hulme Exhibitioner of Brasenose College, Oxford; Senior Mathematical Master of Bradford Grammar School. Crown 8vo., 2*s*.

MURRAY.—PLANE TRIGONOMETRY FOR COLLEGES AND SECONDARY SCHOOLS. By DANIEL A. MURRAY, B.A., Ph.D., Instructor in Mathematics in Cornell University. Crown 8vo., 3*s*. 6*d*. With Logarithmic and Trigonometric Tables. Crown 8vo., 5*s*.

SMITH.—ELEMENTARY TRIGONOMETRY. By J. HAMBLIN SMITH, M.A. Crown 8vo., 4*s*. 6*d*. Key, 7*s*. 6*d*.

OPTICS, PHOTOGRAPHY, ETC.

ABNEY.—A TREATISE ON PHOTOGRAPHY. By Sir WILLIAM DE WIVELESLIE ABNEY, K.C.B., F.R.S., Principal Assistant Secretary of the Secondary Department of the Board of Education. With 134 Illustrations. Fcp. 8vo., 5*s*.

DRUDE.—THE THEORY OF OPTICS. By PAUL DRUDE, Professor of Physics at the University of Giessen. Translated from the German by C. RIBORG MANN and ROBERT A. MILLIKAN, Assistant Professors of Physics at the University of Chicago. With 110 Diagrams. 8vo., 15*s*. net.

GLAZEBROOK.—PHYSICAL OPTICS. By R. T. GLAZEBROOK, M.A., F.R.S., Principal of University College, Liverpool. With 183 Woodcuts of Apparatus, etc. Fcp. 8vo., 6*s*.

VANDERPOEL.—COLOR PROBLEMS: a Practical Manual for the Lay Student of Color. By EMILY NOYES VANDRRPOEL. With 117 Plates in Color. Square 8vo., 21*s*. net.

WRIGHT.—OPTICAL PROJECTION: a Treatise on the Use of the Lantern in Exhibition and Scientific Demonstration. By LEWIS WRIGHT, *Author of* 'Light: a Course of Experimental Optics'. With 232 Illustrations. *Crown 8vo., 6s.*

SOUND, LIGHT, HEAT, AND THERMODYNAMICS.

DEXTER.—ELEMENTARY PRACTICAL SOUND, LIGHT AND HEAT. By JOSEPH S. DEXTER, B.Sc. (Lond.), Physics Master, Technical Day School, The Polytechnic Institute, Regent Street. With 152 Illustrations. Crown 8vo., 2*s.* 6*d.*

EMTAGE.—LIGHT. By W. T. A. EMTAGE, M.A., Director of Education, Mauritius. With 232 Illustrations. Crown 8vo., 6*s*

HELMHOLTZ.—ON THE SENSATIONS OF TONE AS A PHYSIOLOGICAL BASIS FOR THE THEORY OF MUSIC. By HERMANN VON HELMHOLTZ. Royal 8vo., 28*s.*

MAXWELL.—THEORY OF HEAT. By J. CLERK MAXWELL M.A., F.R.SS., L. and E. With Corrections and Additions by Lord RAYLEIGH. With 38 Illustrations. Fcp. 8vo., 4*s.* 6*d.*

SMITH.—THE STUDY OF HEAT. By J. HAMBLIN SMITH, M.A., of Gonville and Caius College, Cambridge. Crown 8vo., 3*s.*

TYNDALL.—Works by JOHN TYNDALL, D.C.L., F.R.S. See p. 36.

WORMELL.—A CLASS-BOOK OF THERMODYNAMICS. By RICHARD WORMELL, B.Sc., M.A. Fcp. 8vo., 1*s.* 6*d.*

WRIGHT.—Works by MARK R. WRIGHT, M.A.

SOUND, LIGHT, AND HEAT. With 160 Diagrams and Illustrations. Crown 8vo., 2*s.* 6*d.*

ADVANCED HEAT. With 136 Diagrams and numerous Examples and Examination Papers. Crown 8vo., 4*s.* 6*d.*

STEAM, OIL, AND GAS ENGINES.

BALE.—A HAND-BOOK FOR STEAM USERS; being Rules for Engine Drivers and Boiler Attendants, with Notes on Steam Engine and Boiler Management and Steam Boiler Explosions. By M. POWIS BALE, M.I.M.E., A.M.I.C.E. Fcp. 8vo., 2*s.* 6*d.*

CLERK.—THE GAS AND OIL ENGINE. By DUGALD CLERK, Member of the Institution of Civil Engineers, Fellow of the Chemical Society, Member of the Royal Institution, Fellow of the Institute of Patent Agents. With 228 Illustrations. 8vo., 15*s.*

STEAM, OIL, AND GAS ENGINES—*Continued.*

HOLMES.—THE STEAM ENGINE. By GEORGE C. V. HOLMES, Chairman of the Board of Works, Ireland. With 212 Illustrations. Fcp. 8vo., 6*s.*

NEILSON.—THE STEAM TURBINE. By ROBERT M. NEILSON, Whitworth Exhibitioner, Associate Member of the Institute of Mechanical Engineers, Lecturer on Steam and the Steam Engine at the Heginbottom Technical School, Ashton-under-Lyne. With 145 Illustrations. 8vo., 7*s.* 6*d.* net.

NORRIS.—A PRACTICAL TREATISE ON THE 'OTTO' CYCLE GAS ENGINE. By WILLIAM NORRIS, M.I.Mech.E. With 207 Illustrations. 8vo. 10*s.* 6*d.*

RIPPER.—Works by WILLIAM RIPPER, Professor of Engineering in the Technical Department of University College, Sheffield.

STEAM. With 185 Illustrations. Crown 8vo., 2*s.* 6*d.*

STEAM ENGINE THEORY AND PRACTICE. With 438 Illustrations. 8vo., 9*s.*

SENNETT AND ORAM.—THE MARINE STEAM ENGINE: A Treatise for Engineering Students, Young Engineers and Officers of the Royal Navy and Mercantile Marine. By the late RICHARD SENNETT, Engineer-in-Chief of the Navy, etc.; and HENRY J. ORAM, Senior Engineer Inspector at the Admiralty, Inspector of Machinery in H.M. Fleet, etc. With 414 Diagrams. 8vo., 21*s.*

STROMEYER.—MARINE BOILER MANAGEMENT AND CONSTRUCTION. Being a Treatise on Boiler Troubles and Repairs, Corrosion, Fuels, and Heat, on the properties of Iron and Steel, on Boiler Mechanics, Workshop Practices, and Boiler Design. By C. E. STROMEYER, Chief Engineer of the Manchester Steam Users' Association, Member of Council of the Institution of Naval Architects, etc. With 452 Diagrams, etc. 8vo., 12*s.* net.

ARCHITECTURE, BUILDING CONSTRUCTION, ETC.

ADVANCED BUILDING CONSTRUCTION. By the Author of 'Rivingtons' Notes on Building Construction'. With 385 Illustrations. Crown 8vo., 4*s.* 6*d.*

BURRELL.—BUILDING CONSTRUCTION. By EDWARD J. BURRELL, Second Master of the People's Palace Technical School, London. With 303 Working Drawings. Crown 8vo., 2*s.* 6*d.*

GWILT.—AN ENCYCLOPÆDIA OF ARCHITECTURE. By JOSEPH GWILT, F.S.A. Revised (1888), with Alterations and Considerable Additions by WYATT PAPWORTH. With 1700 Engravings. 8vo., 21*s.* net.

PARKER AND UNWIN.—THE ART OF BUILDING A HOME: A Collection of Lectures and Illustrations. By BARRY PARKER and RAYMOND UNWIN. With 68 Full-page Plates. 8vo, 10*s.* 6*d.* net.

RICHARDS.—BRICKLAYING AND BRICKCUTTING. By H. W. RICHARDS, Examiner in Brickwork and Masonry to the City and Guilds of London Institute, Head of Building Trades Department, Northern Polytechnic Institute, London, N. With over 200 Illustrations. 8vo., 3*s.* 6*d.*

ARCHITECTURE, BUILDING CONSTRUCTION, ETC.—*Continued.*

SEDDON.—BUILDER'S WORK AND THE BUILDING TRADES. By Col. H. C. SEDDON, R.E., late Superintending Engineer, H.M.'s Dockyard, Portsmouth; Examiner in Building Construction, Science and Art Department, South Kensington. With numerous Illustrations. Medium 8vo., 16*s.*

VALDER.—BOOK OF TABLES, giving the Cubic Contents of from One to Thirty Pieces Deals, Battens and Scantlings of the Sizes usually imported or used in the Building Trades, together with an Appendix showing a large number of sizes, the Contents of which may be found by referring to the aforesaid Tables. By THOMAS VALDER. Oblong 4to., 6*s.* net.

RIVINGTONS' COURSE OF BUILDING CONSTRUCTION.

NOTES ON BUILDING CONSTRUCTION. Arranged to meet the requirements of the syllabus of the Board of Education. Medium 8vo.

Part I. Elementary Stage. With 552 Illustrations, 9*s.* net.

Part II. Advanced Stage. With 479 Illustrations, 9*s.* net.

Part III. Materials. Course for Honours. With 188 Illustrations, 18*s.* net.

Part IV. Calculations for Building Structures. Course for Honours. With 551 Illustrations, 13*s.* net.

ELECTRICITY AND MAGNETISM.

ARRHENIUS.—A TEXT-BOOK OF ELECTROCHEMISTRY. By SVANTE ARRHENIUS, Professor at the University of Stockholm. Translated from the German Edition by JOHN MCCRAE, Ph.D. With 58 Illustrations. 8vo., 9*s.* 6*d.* net.

CARUS-WILSON.—ELECTRO-DYNAMICS: the Direct-Current Motor. By CHARLES ASHLEY CARUS-WILSON, M.A. Cantab. With 71 Diagrams, and a Series of Problems, with Answers. Crown 8vo., 7*s.* 6*d.*

CUMMING.—ELECTRICITY TREATED EXPERIMENTALLY. By LINNÆUS CUMMING, M.A. With 242 Illustrations. Cr. 8vo., 4*s.* 6*d.*

DAY.—EXERCISES IN ELECTRICAL AND MAGNETIC MEASUREMENTS, with Answers. By R. E. DAY. 12mo., 3*s.* 6*d.*

FITZGERALD.—THE SCIENTIFIC WRITINGS OF THE LATE GEORGE FRANCIS FITZGERALD, Sc.D., F.R.S., F.R.S.E., Fellow of Trinity College, Dublin. Collected and Edited, with an Historical Introduction, by JOSEPH LARMOR, Sec. R.S., Fellow of St. John's College, Cambridge. With Portrait. 8vo., 15*s.*

GORE.—THE ART OF ELECTRO-METALLURGY, including all known Processes of Electro-Deposition. By G. GORE, LL.D., F.R.S. With 56 Illustrations. Fcp. 8vo., 6*s.*

HENDERSON.—Works by JOHN HENDERSON, D.Sc., F.R.S.E.

PRACTICAL ELECTRICITY AND MAGNETISM. With 159 Illustrations and Diagrams. Crown 8vo., 6*s.* 6*d.*

PRELIMINARY PRACTICAL MAGNETISM AND ELECTRICITY. Crown 8vo., 1*s.*

ELECTRICITY AND MAGNETISM—*Continued.*

JENKIN.—ELECTRICITY AND MAGNETISM. By FLEEMING JENKIN, F.R.S., M.I.C.E. With 177 Illustrations. Fcp. 8vo., 3*s.* 6*d.*

JOUBERT.—ELEMENTARY TREATISE ON ELECTRICITY AND MAGNETISM. Founded on JOUBERT'S 'Traité Élémentaire d'Électricité'. By G. C. FOSTER, F.R.S., and E. ATKINSON, Ph.D. With Illustrations. Crown 8vo. [*New Edition in the Press.*

JOYCE.—EXAMPLES IN ELECTRICAL ENGINEERING. By SAMUEL JOYCE, A.I.E.E. Crown 8vo., 5*s.*

MACLEAN AND *MARCHANT.*—ELEMENTARY QUESTIONS IN ELECTRICITY AND MAGNETISM. With Answers. Compiled by MAGNUS MACLEAN, D.Sc., M.I.E.E., and E. W. MARCHANT, D.Sc., A.I.E.E. Crown 8vo., 1*s.*

MERRIFIELD.—MAGNETISM AND DEVIATION OF THE COMPASS. By JOHN MERRIFIELD, LL.D., F.R.A.S., 18mo., 2*s.* 6*d.*

PARR.—PRACTICAL ELECTRICAL TESTING IN PHYSICS AND ELECTRICAL ENGINEERING. By G. D. ASPINALL PARR, Assoc. M.I.E.E. With 231 Illustrations. 8vo., 8*s.* 6*d.*

POYSER.—Works by A. W. POYSER, M.A.

MAGNETISM AND ELECTRICITY. With 235 Illustrations. Crown 8vo., 2*s.* 6*d.*

ADVANCED ELECTRICITY AND MAGNETISM. With 317 Illustrations. Crown 8vo., 4*s.* 6*d.*

RHODES.—AN ELEMENTARY TREATISE ON ALTERNATING CURRENTS. By W. G. RHODES, M.Sc. (Vict.), Consulting Engineer. With 80 Diagrams 8vo., 7*s.* 6*d.* net.

SLINGO AND *BROOKER.*—Works by W. SLINGO and A. BROOKER.

ELECTRICAL ENGINEERING FOR ELECTRIC LIGHT ARTISANS AND STUDENTS. With 371 Illustrations. Crown 8vo., 12*s.*

PROBLEMS AND SOLUTIONS IN ELEMENTARY ELECTRICITY AND MAGNETISM. With 98 Illustrations. Cr. 8vo., 2*s.*

TYNDALL.—Works by JOHN TYNDALL, D.C.L., F.R.S. See p. 36.

TELEGRAPHY AND THE TELEPHONE.

HOPKINS. — TELEPHONE LINES AND THEIR PROPERTIES. By WILLIAM J. HOPKINS, Professor of Physics in the Drexel Institute, Philadelphia. Crown 8vo., 6*s.*

PREECE AND *SIVEWRIGHT.*—TELEGRAPHY. By Sir W. H. PREECE, K.C.B., F.R.S., V.P. Inst., C.E., etc., Consulting Engineer and Electrician, Post Office Telegraphs; and Sir J. SIVEWRIGHT, K.C.M.G., General Manager, South African Telegraphs. With 267 Illustrations. Fcp. 8vo., 6*s.*

ENGINEERING, STRENGTH OF MATERIALS, ETC.

ANDERSON.—THE STRENGTH OF MATERIALS AND STRUCTURES: the Strength of Materials as depending on their Quality and as ascertained by Testing Apparatus. By Sir J. ANDERSON, C.E., LL.D., F.R.S.E. With 66 Illustrations. Fcp. 8vo., 3*s.* 6*d.*

BARRY.—RAILWAY APPLIANCES: a Description of Details of Railway Construction subsequent to the completion of the Earthworks and Structures. By Sir JOHN WOLFE BARRY, K.C.B., F.R.S., M.I.C.E. With 218 Illustrations. Fcp. 8vo., 4*s.* 6*d.*

DIPLOCK.—A NEW SYSTEM OF HEAVY GOODS TRANSPORT ON COMMON ROADS. By BRAHAM JOSEPH DIPLOCK. With 27 Illustrations. 8vo.

GOODMAN.—MECHANICS APPLIED TO ENGINEERING. By JOHN GOODMAN, Wh.Sch., A.M.I.C.E., M.I.M.E., Professor of Engineering in the Yorkshire College, Leeds (Victoria University). With 620 Illustrations and numerous Examples. Crown 8vo., 7*s.* 6*d.* net.

LOW.—A POCKET-BOOK FOR MECHANICAL ENGINEERS. By DAVID ALLAN LOW (Whitworth Scholar), M.I.Mech.E., Professor of Engineering, East London Technical College (People's Palace), London. With over 1000 specially prepared Illustrations. Fcp. 8vo., gilt edges, rounded corners, 7*s.* 6*d.*

PARKINSON.—LIGHT RAILWAY CONSTRUCTION. By RICHARD MARION PARKINSON, Assoc.M.Inst.C.E. With 85 Diagrams. 8vo., 10*s.* 6d. net.

SMITH.—GRAPHICS, or the Art of Calculation by Drawing Lines, applied especially to Mechanical Engineering. By ROBERT H. SMITH, Professor of Engineering, Mason College, Birmingham. Part I. With separate Atlas of 29 Plates containing 97 Diagrams. 8vo., 15*s.*

STONEY.—THE THEORY OF STRESSES IN GIRDERS AND SIMILAR STRUCTURES; with Practical Observations on the Strength and other Properties of Materials. By BINDON B. STONEY, LL.D., F.R.S., M.I.C.E. With 5 Plates and 143 Illust. in the Text. Royal 8vo., 36*s.*

UNWIN.—THE TESTING OF MATERIALS OF CONSTRUCTION. A Text-book for the Engineering Laboratory and a Collection of the Results of Experiment. By W. CAWTHORNE UNWIN, F.R.S., B.Sc. With 5 Plates and 188 Illustrations and Diagrams. 8vo., 16*s.* net.

WARREN.—ENGINEERING CONSTRUCTION IN IRON, STEEL, AND TIMBER. By WILLIAM HENRY WARREN, Challis Professor of Civil and Mechanical Engineering, University of Sydney. With 13 Folding Plates and 375 Diagrams. Royal 8vo., 16*s.* net.

WHEELER.—THE SEA COAST: Destruction, Littoral Drift, Protection. By W. H. WHEELER, M.Inst. C.E. With 38 Illustrations and Diagram. Medium 8vo., 10*s.* 6*d.* net.

LONGMANS' CIVIL ENGINEERING SERIES.

CIVIL ENGINEERING AS APPLIED TO CONSTRUCTION. By LEVESON FRANCIS VERNON-HARCOURT, M.A., M.Inst.C.E. With 368 Illustrations. Medium 8vo., 14*s.* net.

CONTENTS.—Materials, Preliminary Works, Foundations and Roads—Railway Bridge and Tunnel Engineering—River and Canal Engineering—Irrigation Works—Dock Works and Maritime Engineering—Sanitary Engineering.

NOTES ON DOCKS AND DOCK CONSTRUCTION. By C. COLSON, C.B., M.Inst.C.E. With 365 Illustrations. Medium 8vo., 21*s.* net.

CALCULATIONS IN HYDRAULIC ENGINEERING: a Practical Text-Book for the use of Students, Draughtsmen and Engineers. By T. CLAXTON FIDLER, M.Inst.C.E.

Part I. Fluid Pressure and the Calculation of its Effects in Engineering Structures. With numerous Illustns. and Examples. 8vo., 6*s.* 6*d.* net.

Part II. Calculations in Hydro-Kinetics. With numerous Illustrations and Examples. 8vo., 7*s.* 6*d.* net.

RAILWAY CONSTRUCTION. By W. H. MILLS, M.I.C.E., Engineer-in-Chief of the Great Northern Railway of Ireland. With 516 Illustrations and Diagrams. 8vo., 18*s.* net.

PRINCIPLES AND PRACTICE OF HARBOUR CONSTRUCTION. By WILLIAM SHIELD, F.R.S.E., M.Inst.C.E. With 97 Illustrations. Medium 8vo., 15*s.* net.

TIDAL RIVERS: their (1) Hydraulics, (2) Improvement, (3) Navigation. By W. H. WHEELER, M.Inst.C.E. With 75 Illustrations. Medium 8vo., 16*s.* net.

MACHINE DRAWING AND DESIGN.

LOW.—Works by DAVID ALLAN LOW, Professor of Engineering, East London Technical College (People's Palace).

IMPROVED DRAWING SCALES. 6*d.* in case.

AN INTRODUCTION TO MACHINE DRAWING AND DESIGN. With 153 Illustrations and Diagrams. Crown 8vo, 2*s.* 6*d.*

LOW AND BEVIS.—A MANUAL OF MACHINE DRAWING AND DESIGN. By DAVID ALLAN LOW and ALFRED WILLIAM BEVIS, M.I.Mech.E. With 700 Illustrations. 8vo., 7*s.* 6*d.*

UNWIN.—THE ELEMENTS OF MACHINE DESIGN. By W. CAWTHORNE UNWIN, F.R.S.

Part I. General Principles, Fastenings, and Transmissive Machinery. With 345 Diagrams, etc. Fcp. 8vo., 7*s.* 6*d.*

Part II. Chiefly on Engine Details. With 259 Illustrations. *Fcp. 8vo., 6s.*

NAVAL ARCHITECTURE.

ATTWOOD.—TEXT-BOOK OF THEORETICAL NAVAL ARCHITECTURE: a Manual for Students of Science Classes and Draughtsmen Engaged in Shipbuilders' and Naval Architects' Drawing Offices. By EDWARD LEWIS ATTWOOD, Assistant Constructor, Royal Navy. With 114 Diagrams. Crown 8vo., 7*s*. 6*d*.

WATSON.—NAVAL ARCHITECTURE: A Manual of Laying-off Iron, Steel and Composite Vessels. By THOMAS H. WATSON, Lecturer on Naval Architecture at the Durham College of Science, Newcastle-upon-Tyne. With numerous Illustrations. Royal 8vo., 15*s*. net.

WORKSHOP APPLIANCES, ETC.

NORTHCOTT.—LATHES AND TURNING, Simple, Mechanical and Ornamental. By W. H. NORTHCOTT. With 338 Illustrations. 8vo., 18*s*.

SHELLEY.—WORKSHOP APPLIANCES, including Descriptions of some of the Gauging and Measuring Instruments, Hand-cutting Tools, Lathes, Drilling, Planeing, and other Machine Tools used by Engineers. By C. P. B. SHELLEY, M.I.C.E. With an additional Chapter on Milling by R. R. LISTER. With 323 Illustrations. Fcp. 8vo., 5*s*.

MINERALOGY, MINING, METALLURGY, ETC.

BAUERMAN.—Works by HILARY BAUERMAN, F.G.S.

SYSTEMATIC MINERALOGY. With 373 Illustrations. Fcp. 8vo., 6*s*.

DESCRIPTIVE MINERALOGY. With 236 Illustrations. Fcp. 8vo., 6*s*.

BREARLEY AND IBBOTSON. — THE ANALYSIS OF STEEL-WORKS MATERIALS. By HARRY BREARLEY and FRED IBBOTSON, B.Sc. (Lond.), Demonstrator of Micrographic Analysis, University College, Sheffield. With 85 Illustrations. 8vo., 14*s*. net.

GORE.—THE ART OF ELECTRO-METALLURGY. By G. GORE, LL.D., F.R.S. With 56 Illustrations. Fcp. 8vo., 6*s*.

HUNTINGTON AND M'MILLAN.—METALS: their Properties and Treatment. By A. K. HUNTINGTON, Professor of Metallurgy in King's College, London, and W. G. M'MILLAN, Lecturer on Metallurgy in Mason's College, Birmingham. With 122 Illustrations. Fcp. 8vo., 7*s*. 6*d*.

LUPTON.—Works by ARNOLD LUPTON, M.I.C.E., F.G.S., etc.

MINING. An Elementary Treatise on the Getting of Minerals. With 596 Diagrams and Illustrations. Crown 8vo., 9*s*. net.

A PRACTICAL TREATISE ON MINE SURVEYING. With 209 Illustrations. 8vo., 12*s*. net.

RHEAD.—METALLURGY. By E. L. RHEAD, Lecturer on Metallurgy at the Municipal Technical School, Manchester. With 94 Illustrations. Fcp. 8vo., 3*s*. 6*d*.

RHEAD AND SEXTON.—ASSAYING AND METALLURGICAL ANALYSIS for the use of Students, Chemists and Assayers. By E. L. RHEAD, Lecturer on Metallurgy, Municipal School of Technology, Manchester; and A. HUMBOLDT SEXTON, F.I.C., F.C.S., Professor of Metallurgy, Glasgow and West of Scotland Technical College. 8vo., 10*s*. 6*d*. net.

RUTLEY.—THE STUDY OF ROCKS: an Elementary Text-book of Petrology. By F. RUTLEY, F.G.S. With 6 Plates and 88 other Illustrations. Fcp. 8vo., 4*s*. 6*d*.

ASTRONOMY, NAVIGATION, ETC.

ABBOTT.—ELEMENTARY THEORY OF THE TIDES: the Fundamental Theorems Demonstrated without Mathematics and the Influence on the Length of the Day Discussed. By T. K. ABBOTT, B.D., Fellow and Tutor, Trinity College, Dublin. Crown 8vo., 2*s.*

BALL.—Works by Sir ROBERT S. BALL, LL.D., F.R.S.

ELEMENTS OF ASTRONOMY. With 130 Figures and Diagrams. Fcp. 8vo., 6*s.* 6*d.*

A CLASS-BOOK OF ASTRONOMY. With 41 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

GILL.—TEXT-BOOK ON NAVIGATION AND NAUTICAL ASTRONOMY. By J. GILL, F.R.A.S., late Head Master of the Liverpool Corporation Nautical College. 8vo., 10*s.* 6*d.*

GOODWIN.—AZIMUTH TABLES FOR THE HIGHER DECLINATIONS. (Limits of Declination 24° to 30°, both inclusive.) Between the Parallels of Latitude 0° and 60°. With Examples of the Use of the Tables in English and French. By H. B. GOODWIN, Naval Instructor, Royal Navy. Royal 8vo., 7*s.* 6*d.*

HERSCHEL.—OUTLINES OF ASTRONOMY. By Sir JOHN F. W. HERSCHEL, Bart., K.H., etc. With 9 Plates and numerous Diagrams. 8vo., 12*s.*

LAUGHTON.—AN INTRODUCTION TO THE PRACTICAL AND THEORETICAL STUDY OF NAUTICAL SURVEYING. By JOHN KNOX LAUGHTON, M.A., F.R.A.S. With 35 Diagrams. Crown 8vo., 6*s.*

LOWELL.—MARS. By PERCIVAL LOWELL, Fellow American Academy, Member Royal Asiatic Society, Great Britain and Ireland, etc. With 24 Plates. 8vo., 12*s.* 6*d.*

MARTIN.—NAVIGATION AND NAUTICAL ASTRONOMY. Compiled by Staff Commander W. R. MARTIN, R.N. Royal 8vo., 18*s.*

MERRIFIELD.—A TREATISE ON NAVIGATION. For the Use of Students. By J. MERRIFIELD, LL.D., F.R.A.S., F.M.S. With Charts and Diagrams. Crown 8vo., 5*s.*

PARKER.—ELEMENTS OF ASTRONOMY. With Numerous Examples and Examination Papers. By GEORGE W. PARKER, M.A., of Trinity College, Dublin. With 84 Diagrams. 8vo., 5*s.* 6*d.* net.

WEBB.—CELESTIAL OBJECTS FOR COMMON TELESCOPES. By the Rev. T. W. WEBB, M.A., F.R.A.S. Fifth Edition, Revised and greatly Enlarged by the Rev. T. E. ESPIN, M.A., F.R.A.S. (Two Volumes.) Vol. I., with Portrait and a Reminiscence of the Author, 2 Plates, and numerous Illustrations. Crown 8vo., 6*s.* Vol. II., with numerous Illustrations. Crown 8vo., 6*s.* 6*d.*

WORKS BY RICHARD A. PROCTOR.

THE MOON: Her Motions, Aspect, Scenery, and Physical Condition. With many Plates and Charts, Wood Engravings, and 2 Lunar Photographs. Crown 8vo., 3*s*. 6*d*.

OTHER WORLDS THAN OURS: the Plurality of Worlds Studied Under the Light of Recent Scientific Researches. With 14 Illustrations; Map, Charts, etc. Crown 8vo., 3*s*. 6*d*.

OUR PLACE AMONG INFINITIES: a Series of Essays contrasting our Little Abode in Space and Time with the Infinities around us. Crown 8vo., 3*s*. 6*d*.

MYTHS AND MARVELS OF ASTRONOMY. Crown 8vo., 3*s*. 6*d*.

LIGHT SCIENCE FOR LEISURE HOURS: Familiar Essays on Scientific Subjects, Natural Phenomena, etc. Crown 8vo., 3*s*. 6*d*.

THE ORBS AROUND US; Essays on the Moon and Planets, Meteors and Comets, the Sun and Coloured Pairs of Suns. Crown 8vo., 3*s*. 6*d*.

THE EXPANSE OF HEAVEN: Essays on the Wonders of the Firmament. Crown 8vo., 3*s*. 6*d*.

OTHER SUNS THAN OURS: a Series of Essays on Suns—Old, Young, and Dead. With other Science Gleanings. Two Essays on Whist, and Correspondence with Sir John Herschel. With 9 Star-Maps and Diagrams. Crown 8vo., 3*s*. 6*d*.

HALF-HOURS WITH THE TELESCOPE: a Popular Guide to the Use of the Telescope as a means of Amusement and Instruction. With 7 Plates. Fcp. 8vo., 2*s*. 6*d*.

NEW STAR ATLAS FOR THE LIBRARY, the School, and the Observatory, in Twelve Circular Maps (with Two Index-Plates). With an Introduction on the Study of the Stars. Illustrated by 9 Diagrams. Cr. 8vo., 5*s*.

THE SOUTHERN SKIES: a Plain and Easy Guide to the Constellations of the Southern Hemisphere. Showing in 12 Maps the position of the principal Star-Groups night after night throughout the year. With an Introduction and a separate Explanation of each Map. True for every Year. 4to., 5*s*.

HALF-HOURS WITH THE STARS: a Plain and Easy Guide to the Knowledge of the Constellations. Showing in 12 Maps the position of the principal Star-Groups night after night throughout the year. With Introduction and a separate Explanation of each Map. True for every Year. 4to., 3*s*. net.

LARGER STAR ATLAS FOR OBSERVERS AND STUDENTS. In Twelve Circular Maps, showing 6000 Stars, 1500 Double Stars, Nebulæ, etc. With 2 Index-Plates. Folio, 15*s*.

OVER.

WORKS BY RICHARD A. PROCTOR—*Continued.*

THE STARS IN THEIR SEASONS: an Easy Guide to a Knowledge of the Star-Groups. In 12 Large Maps. Imperial 8vo., 5*s.*

ROUGH WAYS MADE SMOOTH. Familiar Essays on Scientific Subjects. Crown 8vo., 3*s.* 6*d.*

PLEASANT WAYS IN SCIENCE. Crown 8vo., 3*s.* 6*d.*

NATURE STUDIES. By R. A. PROCTOR, GRANT ALLEN, A. WILSON, T. FOSTER, and E. CLODD. Crown 8vo., 3*s.* 6*d.*

LEISURE READINGS. By R. A. PROCTOR, E. CLODD, A. WILSON, T. FOSTER, and A. C. RANYARD. Crown 8vo., 3*s.* 6*d.*

PHYSIOGRAPHY AND GEOLOGY.

BIRD.—Works by CHARLES BIRD, B.A.

ELEMENTARY GEOLOGY. With Geological Map of the British Isles, and 247 Illustrations. Crown 8vo., 2*s.* 6*d.*

ADVANCED GEOLOGY. A Manual for Students in Advanced Classes and for General Readers. With over 300 Illustrations, a Geological Map of the British Isles (coloured), and a set of Questions for Examination. Crown 8vo., 7*s.* 6*d.*

GREEN.—PHYSICAL GEOLOGY FOR STUDENTS AND GENERAL READERS. By A. H. GREEN, M.A., F.G.S. With 236 Illustrations. 8vo., 21*s.*

MORGAN.—Works by ALEX. MORGAN, M.A., D.Sc., F.R.S.E.

ELEMENTARY PHYSIOGRAPHY. Treated Experimentally. With 4 Maps and 243 Diagrams. Crown 8vo., 2*s.* 6*d.*

ADVANCED PHYSIOGRAPHY. With 215 Illustrations. Crown 8vo., 4*s.* 6*d.*

THORNTON.—Works by J. THORNTON, M.A.

ELEMENTARY PRACTICAL PHYSIOGRAPHY.

Part I. With 215 Illustrations. Crown 8vo., 2*s.* 6*d.*

Part II. With 98 Illustrations. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PHYSIOGRAPHY: an Introduction to the Study of Nature. With 13 Maps and 295 Illustrations. With Appendix on Astronomical Instruments and Measurements. Crown 8vo., 2*s.* 6*d.*

ADVANCED PHYSIOGRAPHY. With 11 Maps and 255 Illustrations. Crown 8vo., 4*s.* 6*d.*

NATURAL HISTORY AND GENERAL SCIENCE.

BEDDARD.—THE STRUCTURE AND CLASSIFICATION OF BIRDS. By FRANK E. BEDDARD, M.A., F.R.S., Prosector and Vice-Secretary of the Zoological Society of London. With 252 Illus. 8vo., 21*s.* net.

FURNEAUX.—Works by WILLIAM FURNEAUX, F.R.G.S.

THE OUTDOOR WORLD; or, The Young Collector's Handbook. With 18 Plates, 16 of which are coloured, and 549 Illustrations in the Text. Crown 8vo., 6*s.* net.

LIFE IN PONDS AND STREAMS. With 8 Coloured Plates and 331 Illustrations in the Text. Crown 8vo., 6*s.* net.

BUTTERFLIES AND MOTHS (British). With 12 Coloured Plates and 241 Illustrations in the Text. Crown 8vo., 6*s.* net.

HUDSON.—BRITISH BIRDS. By W. H. HUDSON, C.M.Z.S. With 8 Coloured Plates from Original Drawings by A. THORBURN, and 8 Plates and 100 Figures by C. E. LODGE, and 3 Illustrations from Photographs. Crown 8vo., 6*s.* net.

MILLAIS.—THE NATURAL HISTORY OF THE BRITISH SURFACE-FEEDING DUCKS. By JOHN GUILLE MILLAIS, F.Z.S., etc. With 6 Photogravures and 66 Plates (41 in colours) from Drawings by the Author ARCHIBALD THORBURN, and from Photographs. Royal 4to., £6 6s. net.

NANSEN.—THE NORWEGIAN NORTH POLAR EXPEDITION, 1893-1896: Scientific Results. Edited by FRIDTJOF NANSEN.

Volume I. With 44 Plates and numerous Illustrations in the Text. Demy 4to., 40*s.* net.

CONTENTS: The *Fram*—The Jurassic Fauna of Cape Flora. With a Geological Sketch of Cape Flora and its Neighbourhood—Fossil Plants from Franz Josef Land—An Account of the Birds—Crustacea.

Volume II. With 2 Charts and 17 Plates. Demy 4to., 30*s.* net.

CONTENTS: Astronomical Observations—Terrestrial Magnetism—Results of the Pendulum—Observations and some Remarks on the Constitution of the Earth's Crust.

Volume III. With 33 Plates. Demy 4to., 32*s.* net.

CONTENTS: The Oceanography of the North Polar Basin—On Hydrometers and the Surface Tension of Liquids.

STANLEY.—A FAMILIAR HISTORY OF BIRDS. By E. STANLEY, D.D., formerly Bishop of Norwich. With 160 Illustrations. Crown 8vo., 3*s.* 6*d*

MANUFACTURES, TECHNOLOGY, ETC.

BELL.—JACQUARD WEAVING AND DESIGNING. By F. T. BELL. With 199 Diagrams. 8vo., 12*s.* net.

CROSS AND BEVAN.—Works by C. F. CROSS and E. J. BEVAN.

CELLULOSE: an Outline of the Chemistry of the Structural Elements of Plants. With reference to their Natural History and Industrial Uses. (C. F. CROSS, E. J. BEVAN and C. BEADLE.) With 14 Plates. Crown 8vo., 12*s.* net.

RESEARCHES ON CELLULOSE, 1895-1900. Crown 8vo., 6*s.* net.

MANUFACTURES, TECHNOLOGY, ETC.—*Continued.*

MORRIS AND WILKINSON.—THE ELEMENTS OF COTTON SPINNING. By JOHN MORRIS and F. WILKINSON. With a Preface by Sir B. A. DOBSON, C.E., M.I.M.E. With 169 Diagrams and Illustrations. Crown 8vo., 7*s.* 6*d.* net.

RICHARDS.—BRICKLAYING AND BRICK-CUTTING. By H. W. RICHARDS, Examiner in Brickwork and Masonry to the City and Guilds of London Institute, Head of Building Trades Department, Northern Polytechnic Institute, London, N. With over 200 Illustrations. Med. 8vo., 3*s.* 6*d.*

TAYLOR.—COTTON WEAVING AND DESIGNING. By JOHN T. TAYLOR. With 373 Diagrams. Crown 8vo., 7*s.* 6*d.* net.

WATTS.—AN INTRODUCTORY MANUAL FOR SUGAR GROWERS. By FRANCIS WATTS, F.C.S., F.I.C. With 20 Illustrations. Crown 8vo., 6*s.*

HEALTH AND HYGIENE.

ASHBY.—HEALTH IN THE NURSERY. By HENRY ASHBY, M.D., F.R.C.P. With 25 Illustrations. Crown 8vo., 3*s.* net.

BUCKTON.—HEALTH IN THE HOUSE. By Mrs. C. M. BUCKTON. With 41 Woodcuts and Diagrams. Crown 8vo., 2*s.*

CORFIELD.—THE LAWS OF HEALTH. By W. H. CORFIELD, M.A., M.D. Fcp. 8vo., 1*s.* 6*d.*

FURNEAUX.—ELEMENTARY PRACTICAL HYGIENE.—Section I. By WILLIAM S. FURNEAUX. With 146 Illustrations. Cr. 8vo., 2*s.* 6*d.*

NOTTER AND FIRTH.—Works by J. L. NOTTER, M.A., M.D., and R. H. FIRTH, F.R.C.S.

HYGIENE. With 95 Illustrations. Crown 8vo., 3*s.* 6*d.*

PRACTICAL DOMESTIC HYGIENE. With 83 Illustrations. Crown 8vo., 2*s.* 6*d.*

POORE.—Works by GEORGE VIVIAN POORE, M.D.

ESSAYS ON RURAL HYGIENE. Crown 8vo., 6*s.* 6*d.*

THE DWELLING-HOUSE. With 36 Illustrations. Crown 8vo., 3*s.* 6*d.*

THE EARTH IN RELATION TO THE PRESERVATION AND DESTRUCTION OF CONTAGIA: being the Milroy Lectures delivered at the Royal College of Physicians in 1899, together with other Papers on Sanitation. With 13 Illustrations. Crown 8vo., 5*s.*

WILSON.—A MANUAL OF HEALTH-SCIENCE. By ANDREW WILSON, F.R.S.E., F.L.S., etc. With 74 Illustrations. Crown 8vo., 2*s.* 6*d.*

MEDICINE AND SURGERY.

ASHBY AND WRIGHT.—THE DISEASES OF CHILDREN, MEDICAL AND SURGICAL. By HENRY ASHBY, M.D., Lond., F.R.C.P., Physician to the General Hospital for Sick Children, Manchester; and G. A. WRIGHT, B.A., M.B. Oxon., F.R.C.S., Eng., Assistant-Surgeon to the Manchester Royal Infirmary, and Surgeon to the Children's Hospital. Enlarged and Improved Edition. With 192 Illustrations. 8vo., 25*s.*

BENNETT.—Works by SIR WILLIAM BENNETT, K.C.V.O., F.R.C.S., Surgeon to St. George's Hospital; Member of the Board of Examiners, Royal College of Surgeons of England.

CLINICAL LECTURES ON VARICOSE VEINS OF THE LOWER EXTREMITIES. With 3 Plates. 8vo., 6*s.*

ON VARICOCELE; A PRACTICAL TREATISE. With 4 Tables and a Diagram. 8vo., 5*s.*

CLINICAL LECTURES ON ABDOMINAL HERNIA: chiefly in relation to Treatment, including the Radical Cure. With 12 Diagrams in the Text. 8vo., 8*s.* 6*d.*

ON VARIX, ITS CAUSES AND TREATMENT, WITH ESPECIAL REFERENCE TO THROMBOSIS. 8vo., 3*s.* 6*d.*

THE PRESENT POSITION OF THE TREATMENT OF SIMPLE FRACTURES OF THE LIMBS. 8vo., 2*s.* 6*d.*

LECTURES ON THE USE OF MASSAGE AND EARLY PASSIVE MOVEMENTS IN RECENT FRACTURES AND OTHER COMMON SURGICAL INJURIES: The Treatment of Internal Derangements of the Knee Joint and Management of Stiff Joints. With 17 Illustrations. 8vo., 6*s.*

BENTLEY.—A TEXT-BOOK OF ORGANIC MATERIA MEDICA. Comprising a Description of the Vegetable and Animal Drugs of the British Pharmacopœia, with some others in common use. Arranged Systematically, and Especially Designed for Students. By ROBERT BENTLEY, M.R.C.S. Eng., F.L.S. With 62 Illustrations on Wood. Crown 8vo., 7*s.* 6*d*

CABOT.—A GUIDE TO THE CLINICAL EXAMINATION OF THE BLOOD FOR DIAGNOSTIC PURPOSES. By RICHARD C. CABOT, M.D., Physician to Out-patients, Massachusetts General Hospital. With 3 Coloured Plates and 28 Illustrations in the Text. 8vo., 16*s.*

CARR, PICK, DORAN, AND DUNCAN.—THE PRACTITIONER'S GUIDE. By J. WALTER CARR, M.D. (Lond.), F.R.C.P.; T. PICKERING PICK, F.R.C.S.; ALBAN H. G. DORAN, F.R.C.S.; ANDREW DUNCAN, M.D., B.Sc. (Lond.), F.R.C.S., M.R.C.P. 8vo., 21*s.* net.

CELLI.—MALARIA, ACCORDING TO THE NEW RESEARCHES. By Prof. ANGELO CELLI, Director of the Institute of Hygiene, University of Rome. Translated from the Second Italian Edition by JOHN JOSEPH EYRE, M.R.C.P., L.R.C.S. Ireland, D.P.H. Cambridge. With an Introduction by Dr. PATRICK MANSON, Medical Adviser to the Colonial Office. 8vo., 10*s.* 6*d.*

MEDICINE AND SURGERY—*Continued.*

CHEYNE AND BURGHARD.—A MANUAL OF SURGIGAL TREATMENT. By W. WATSON CHEYNE, C.B., M.B., F.R.C.S., F.R.S., Professor of Surgery in King's College, London, Surgeon to King's College Hospital, etc.; and F. F. BURGHARD, M.D. and M.S., F.R.C.S., Teacher of Practical Surgery in King's College, London, Surgeon to King's College, Hospital (Lond.), etc.

Part I. The Treatment of General Surgical Diseases, including Inflammation, Suppuration, Ulceration, Gangrene, Wounds and their Complications, Infective Diseases and Tumours; the Administration of Anæsthetics. With 66 Illustrations. Royal 8vo., 10*s.* 6*d.*

Part II. The Treatment of the Surgical Affections of the Tissues, including the Skin and Subcutaneous Tissues, the Nails, the Lymphatic Vessels and Glands, the Fasciæ, Bursæ, Muscles, Tendons and Tendon-sheaths, Nerves, Arteries and Veins. Deformities. With 141 Illustrations. Royal 8vo., 14*s.*

Part III. The Treatment of the Surgical Affections of the Bones. Amputations. With 100 Illustrations. Royal 8vo., 12*s.*

Part IV. The Treatment of the Surgical Affections of the Joints (including Excisions) and the Spine. With 138 Illustrations. Royal 8vo., 14*s.*

Part V. The Treatment of the Surgical Affections of the Head, Face, Jaws, Lips, Larnyx and Trachea; and the Intrinsic Diseases of the Nose, Ear and Larynx, by H. LAMBERT LACK, M.D. (Lond.), F.R.C.S., Surgeon to the Hospital for Diseases of the Throat, Golden Square, and to the Throat and Ear Department, The Children's Hospital, Paddington Green. With 145 Illustrations. Royal 8vo., 18*s.*

Part VI. Section I. The Treatment of the Surgical Affections of the Tongue and Floor of the Mouth, the Pharynx, Neck, Œsophagus, Stomach and Intestines. With 124 Illustrations. Royal 8vo., 18*s.*

Section II. The Treatment of the Surgical Affections of the Rectum, Liver, Spleen, Pancreas, Throat, Breast and Genito-urinary Organs. With Illustrations. Royal 8vo. [*In preparation.*

CLARKE.—POST-MORTEM EXAMINATIONS IN MEDICO-LEGAL AND ORDINARY CASES. With Special Chapters on the Legal Aspects of Post-mortems, and on Certificates of Death. By J. JACKSON CLARKE, M.B. Lond., F.R.C.S., Assistant Surgeon at the North-west London and City Orthopædic Hospitals, etc. Fcp. 8vo., 2*s.* 6*d.*

COATS.—A MANUAL OF PATHOLOGY. By JOSEPH COATS, M.D., late Professor of Pathology in the University of Glasgow. Fourth Edition. Revised throughout and Edited by LEWIS R. SUTHERLAND, M.D., Professor of Pathology, University of St. Andrews. With 490 Illustrations. 8vo., 31*s.* 6*d.*

COOKE.—Works by THOMAS COOKE, F.R.C.S. Eng., B.A., B.Sc., M.D., Paris.

TABLETS OF ANATOMY. Being a Synopsis of Demonstrations given in the Westminster Hospital Medical School. Eleventh Edition in Three Parts, thoroughly brought up to date, and with over 700 Illustrations from all the best Sources, British and Foreign. Post 4to.

Part I. The Bones. 7*s.* 6*d.* net.

Part II. Limbs, Abdomen, Pelvis. 10*s.* 6*d.* net.

Part III. Head and Neck, Thorax, Brain. 10s. 6d. net.

MEDICINE AND SURGERY—*Continued.*

COOKE.—Works by THOMAS COOKE (*continued*).

APHORISMS IN APPLIED ANATOMY AND OPERATIVE SURGERY. Including 100 Typical *vivâ voce* Questions on Surface Marking, etc. Crown 8vo., 3*s.* 6*d.*

DAKIN.—A HANDBOOK OF MIDWIFERY. By WILLIAM RADFORD DAKIN, M.D., F.R.C.P., Obstetric Physician and Lecturer on Midwifery at St. George's Hospital, etc. With 394 Illustrations. Large crown 8vo., 18*s.*

DICKINSON.—Works by W. HOWSHIP DICKINSON, M.D. Cantab., F.R.C.P.

ON RENAL AND URINARY AFFECTIONS. With 12 Plates and 122 Woodcuts. Three Parts. 8vo., £3 4*s.* 6*d.*

THE TONGUE AS AN INDICATION OF DISEASE: being the Lumleian Lectures delivered March, 1888 8vo., 7*s.* 6*d.*

OCCASIONAL PAPERS ON MEDICAL SUBJECTS, 1855-1896. 8vo., 12*s.*

MEDICINE OLD AND NEW. An Address Delivered on the Occasion of the Opening of the Winter Session, 1899-1900, at St. George's Hospital Medical School, on 2nd October, 1899. Crown 8vo., 2*s.* 6*d.*

DUCKWORTH.—Works by SIR DYCE DUCKWORTH, M.D., LL.D., Fellow and Treasurer of the Royal College of Physicians, etc.

THE SEQUELS OF DISEASE: being the Lumleian Lectures, 1896. 8vo., 10*s.* 6*d.*

THE INFLUENCE OF CHARACTER AND RIGHT JUDGMENT IN MEDICINE: the Harveian Oration, 1898. Post 4to. 2*s.* 6*d.*

ERICHSEN.—THE SCIENCE AND ART OF SURGERY; a Treatise on Surgical Injuries, Diseases, and Operations. By Sir JOHN ERIC ERICHSEN, Bart., F.R.S., LL.D. Edin., Hon. M.Ch. and F.R.C.S. Ireland. Illustrated by nearly 1000 Engravings on Wood. 2 vols. Royal 8vo., 48*s.*

FOWLER AND GODLEE.—THE DISEASES OF THE LUNGS. By JAMES KINGSTON FOWLER, M.A., M.D., F.R.C.P., Physician to the Middlesex Hospital and to the Hospital for Consumption and Diseases of the Chest, Brompton, etc.; and RICKMAN JOHN GODLEE, Honorary Surgeon in Ordinary to His Majesty, M.S., F.R.C.S., Fellow and Professor of Clinical Surgery, University College, London, etc. With 160 Illustrations. 8vo., 25*s.*

MEDICINE AND SURGERY—*Continued.*

GARROD.—Works by SIR ALFRED BARING GARROD, M.D., F.R.S., etc.

A TREATISE ON GOUT AND RHEUMATIC GOUT (RHEUMATOID ARTHRITIS). With 6 Plates, comprising 21 Figures (14 Coloured), and 27 Illustrations engraved on Wood. 8vo., 21*s.*

THE ESSENTIALS OF MATERIA MEDICA AND THERAPEUTICS. Crown 8vo., 12*s.* 6*d.*

GOADBY.—THE MYCOLOGY OF THE MOUTH : a Text-Book of Oral Bacteria. By KENNETH W. GOADBY, L.D.S. (Eng.), D.P.H. (Camb.), L.R.C.P., M.R.C.S., Bacteriologist and Lecturer on Bacteriology, National Dental Hospital, etc. With numerous Illustrations. 8vo.

GOODSALL AND MILES.—DISEASES OF THE ANUS AND RECTUM. By D. H. GOODSALL, F.R.C.S., Senior Surgeon, Metropolitan Hospital; Senior Surgeon, St. Mark's Hospital; and W. ERNEST MILES, F.R.C.S., Assistant Surgeon to the Cancer Hospital, Surgeon (out-patients), to the Gordon Hospital, etc. (In Two Parts.) Part I. With 91 Illustrations. 8vo., 7*s.* 6*d.* net.

GRAY.—ANATOMY, DESCRIPTIVE AND SURGICAL. By HENRY GRAY, F.R.S., late Lecturer on Anatomy at St. George's Hospital Medical School. The Fifteenth Edition Enlarged, edited by T. PICKERING PICK, F.R.C.S., Consulting Surgeon to St. George's Hospital, etc., and by ROBERT HOWDEN, M.A., M.B., C.M., Professor of Anatomy in the University of Durham, etc. With 772 Illustrations, a large proportion of which are Coloured, the Arteries being coloured red, the Veins blue, and the Nerves yellow. The attachments of the muscles to the bones, in the section on Osteology, are also shown in coloured outline. Royal 8vo., 32*s.* net.

HALLIBURTON.—Works by W. D. HALLIBURTON, M.D., F.R.S., Professor of Physiology in King's College, London.

A TEXT-BOOK OF CHEMICAL PHYSIOLOGY AND PATHOLOGY. With 104 Illustrations. 8vo., 28*s.*

ESSENTIALS OF CHEMICAL PHYSIOLOGY. With 77 Illustrations. 8vo., 5*s.*

LANG.—THE METHODICAL EXAMINATION OF THE EYE. Being Part I. of a Guide to the Practice of Ophthalmology for Students and Practitioners. By WILLIAM LANG, F.R.C.S. Eng., Surgeon to the Royal London Ophthalmic Hospital, Moorfields, etc. With 15 Illustrations. Crown 8vo., 3*s.* 6*d.*

LUFF.—TEXT-BOOK OF FORENSIC MEDICINE AND TOXICOLOGY. By ARTHUR P. LUFF, M.D., B.Sc. (Lond.), Physician in Charge of Out-Patients and Lecturer on Medical Jurisprudence and Toxicology in St. Mary's Hospital. With 13 full-page Plates (1 in colours) and 33 Illustrations in the Text. 2 vols. Crown 8vo., 24*s.*

MEDICINE AND SURGERY—*Continued.*

LIVERPOOL UNIVERSITY PRESS PUBLICATIONS, THE.

The Thomson Yates Laboratories Reports. Physiology; Pathology; Bacteriology; Tropical Medicine; Hygiene. Edited by RUPERT BOYCE and C. S. SHERRINGTON. With Plates and Illustrations in the text. Demy 4to. Vol I., 1898-9, 10*s.* 6*d.*; Vol. II., 1898-9, 25*s.*; Vol. III., Part I., 1900, 7*s.* 6*d.*; Vol. III., Part II., 1901, 12*s.* 6*d.*; Vol. IV., Part I., 1901, 20*s.*; Vol. IV., Part II., 1902, 21*s.*

THE LIVERPOOL SCHOOL OF TROPICAL MEDICINE MEMOIRS.

With Plates and Illustrations in the text. Demy 4to.

I. Malarial Fever: Its Cause, Prevention and Treatment. Containing full details for the use of Travellers, Sportsmen, Soldiers, and Residents in Malarious Places. By RONALD ROSS, C.B., F.R.S., F.R.C.S. With Frontispiece. 8vo., 2*s.* 6*d.*

II. Report of the Malaria Expedition to West Africa, August, 1899. By RONALD ROSS, C.B., F.R.S., F.R.C.S., H. E. ANNETT, M.D., D.P.H. and E. E. AUSTEN. With Supplementary Reports by Major G. M. GILES, M.B. and R. FIELDING-OULD, M.B. 21*s.*

III. Report of the Malaria Expedition to Nigeria. Part I. Malarial Fever, etc. By H. E. ANNETT, M.D., J. EVERETT DUTTON, M.B. and J. H. ELLIOTT, M.D. 10*s.* 6*d.*

IV. Report of the Malaria Expedition to Nigeria. Part II. Filariasis. By H. E. ANNETT, M.D., J. EVERETT DUTTON, M.B. and J. H. ELLIOTT, M.D. 15*s.*

V. Part I. First Progress Report of the Campaign against Mosquitoes in Sierra Leone (1901). By RONALD ROSS, C.B., F.R.C.S., F.R.S. 8vo., 1*s.*

V. Part II. Second Progress Report of the Campaign against Mosquitoes in Sierra Leone. By M. LOGAN TAYLOR, M.B. 8vo., 1*s.*

VII. Report of the Yellow Fever Expedition to Pará (1900). By H. E. DURHAM, M.B., F.R.C.S., and the late WALTER MYERS, M.B. 4to., 7*s.* 6*d.*

VIII. Report on the Sanitary Conditions of Cape Coast Town. With suggestions as to improvement of same. By M. LOGAN TAYLOR, M.B., Ch.B. 8vo., 1*s.*

MISCELLANEOUS.

Notes on Sanitary Conditions obtaining in Pará. By the MEMBERS OF THE YELLOW FEVER EXPEDITION. 8vo., 1*s.*

PAGET.—Edited by STEPHEN PAGET.

SELECTED ESSAYS AND ADDRESSES. By Sir JAMES PAGET. 8vo., 12*s.* 6*d.* net.

MEMOIRS AND LETTERS OF SIR JAMES PAGET, BART., F.R.S., D.C.L., late Sergeant-Surgeon to Her Majesty Queen Victoria. With 6 Portraits (3 Photogravures) and 4 other Illustrations. 8vo., 12*s.* 6*d.* net.

PICK.—SURGERY: a Treatise for Students and Practitioners. By T. PICKERING PICK, Consulting Surgeon to St. George's Hospital; Senior Surgeon to the Victoria Hospital for Children; H.M. Inspector of Anatomy in England and Wales. With 441 Illustrations. Medium 8vo., 25*s.*

POOLE.—COOKERY FOR THE DIABETIC. By W. H. and Mrs. POOLE. With Preface by Dr. PAVY. Fcap. 8vo., 2*s.* 6*d.*

MEDICINE AND SURGERY—*Continued.*

PROBYN-WILLIAMS.—A PRACTICAL GUIDE TO THE ADMINISTRATION OF ANÆSTHETICS. By R. J. PROBYN-WILLIAMS, M.D., Anæsthetist and Instructor in Anæsthetics at the London Hospital; Lecturer in Anæsthetics at the London Hospital Medical College, etc. With 34 Illustrations. Crown 8vo., 4*s.* 6*d.* net.

QUAIN.—QUAIN'S (SIR RICHARD) DICTIONARY OF MEDICINE. By Various Writers. Third Edition. Edited by H. MONTAGUE MURRAY, M.D., F.R.C.P., Joint Lecturer on Medicine, Charing Cross Medical School, and Physician to Out-Patients, Charing Cross Hospital; assisted by JOHN HAROLD, M.B., B.Ch., B.A.O., Physician to St. John's and St. Elizabeth's Hospital; and W. CECIL BOSANQUET, M.A., M.D., M.R.C.P., Physician to Out-Patients, Victoria Hospital for Children, Chelsea. With 21 Plates (14 in Colour) and numerous Illustrations in the Text. 8vo., 21*s.* net, buckram; or 30*s.* net, half-morocco.

QUAIN.—QUAIN'S (JONES) ELEMENTS OF ANATOMY. The Tenth Edition. Edited by EDWARD ALBERT SCHÄFER, F.R.S., Professor of Physiology in the University of Edinburgh; and GEORGE DANCER THANE, Professor of Anatomy in University College, London.

VOL. I., PART I. EMBRYOLOGY. By E. A. SCHÄFER, F.R.S. With 200 Illustrations. Royal 8vo., 9*s.*

VOL. I., PART II. GENERAL ANATOMY OR HISTOLOGY. By E. A. SCHÄFER, F.R.S. With 291 Illustrations. Royal 8vo., 12*s.* 6*d.*

VOL. II., PART I. OSTEOLOGY—ARTHROLOGY. By G. D. THANE. With 224 Illus. Royal 8vo., 11*s.*

VOL. II., PART II. MYOLOGY—ANGEIOLOGY. By G. D. THANE. With 199 Illustrations. Royal 8vo., 16*s.*

VOL. III., PART I. THE SPINAL CORD AND BRAIN. By E. A. SCHÄFER, F.R.S. With 139 Illustrations. Royal 8vo., 12*s.* 6*d.*

VOL. III., PART II. THE NERVES. By G. D. THANE. With 102 Illustrations. Royal 8vo., 9*s.*

VOL. III., PART III. THE ORGANS OF THE SENSES. By E. A. SCHÄFER, F.R.S. With 178 Illustrations. Royal 8vo., 9*s.*

VOL. III., PART IV. SPLANCHNOLOGY. By E. A. SCHÄFER, F.R.S., and JOHNSON SYMINGTON, M.D. With 337 Illustrations. Royal 8vo., 16*s.*

APPENDIX. SUPERFICIAL AND SURGICAL ANATOMY. By Professor G. D. THANE and Professor R. J. GODLEE, M.S. With 29 Illustrations. Royal 8vo., 6*s.* 6*d.*

SCHÄFER.—Works by E. A. SCHÄFER, F.R.S., Professor of Physiology in the University of Edinburgh.

THE ESSENTIALS OF HISTOLOGY. Descriptive and Practical. For the Use of Students. With 463 Illustrations. 8vo., 9*s.* net.

DIRECTIONS FOR CLASS WORK IN PRACTICAL PHYSIOLOGY: Elementary Physiology of Muscle and Nerve and of the Vascular and Nervous Systems. With 48 Diagrams and 24 pages of plain paper at end for Notes. 8vo., 3*s.* net.

SMALE AND COLYER.—DISEASES AND INJURIES OF THE TEETH, including Pathology and Treatment. By MORTON SMALE, M.R.C.S., L.S.A., L.D.S., Dental Surgeon to St. Mary's Hospital, Dean of the School, Dental Hospital of London, etc.; and J. F. COLYER, L.R.C.P., M.R.C.S., L.D.S., Dental Surgeon to Charing Cross Hospital and to the Dental Hospital of London. Second Edition Revised and Enlarged by J. F. COLYER. With 640 Illustrations. Large crown 8vo., 21*s.* net.

MEDICINE AND SURGERY—*Continued.*

SMITH (*H. F.*).—THE HANDBOOK FOR MIDWIVES. By HENRY FLY SMITH, B.A., M.B. Oxon., M.R.C.S. 41 Woodcuts. Cr. 8vo., 5*s.*

STEVENSON.—WOUNDS IN WAR: the Mechanism of their Production and their Treatment. By Surgeon-Colonel W. F. STEVENSON (Army Medical Staff), A.B., M.B., M.Ch. Dublin University, Professor of Military Surgery, Army Medical School, Netley. With 86 Illustrations. 8vo., 18*s.*

TAPPEINER. — INTRODUCTION TO CHEMICAL METHODS OF CLINICAL DIAGNOSIS. By Dr. H. TAPPEINER, Professor of Pharmacology and Principal of the Pharmacological Institute of the University of Munich. Translated by EDMOND J. MCWEENEY, M.A., M.D. (Royal Univ. of Ireland), L.R.C.P.I., etc. Crown 8vo., 3*s.* 6*d.*

WALLER.—Works by AUGUSTUS D. WALLER, M.D., Lecturer on Physiology at St. Mary's Hospital Medical School, London; late External Examiner at the Victorian University.

AN INTRODUCTION TO HUMAN PHYSIOLOGY. Third Edition, Revised. With 314 Illustrations. 8vo., 18*s.*

LECTURES ON PHYSIOLOGY. First Series. On Animal Electricity. 8vo., 5*s.* net.

VETERINARY MEDICINE, ETC.

FITZWYGRAM.—HORSES AND STABLES. By Lieut.-General Sir F. FITZWYGRAM, Bart. With 56 pages of Illustrations. 8vo., 3*s.* net.

STEEL.—Works by JOHN HENRY STEEL, F.R.C.V.S., F.Z.S., A.V.D., late Professor of Veterinary Science and Principal of Bombay Veterinary College.

A TREATISE ON THE DISEASES OF THE DOG; being a Manual of Canine Pathology. Especially adapted for the use of Veterinary Practitioners and Students. With 88 Illustrations. 8vo., 10*s* 6*d.*

A TREATISE ON THE DISEASES OF THE OX; being a Manual of Bovine Pathology. Especially adapted for the use of Veterinary Practitioners and Students. With 2 Plates and 117 Woodcuts. 8vo. 15*s.*

A TREATISE ON THE DISEASES OF THE SHEEP; being a Manual of Ovine Pathology for the use of Veterinary Practitioners and Students. With Coloured Plate and 99 Woodcuts. 8vo., 12*s.*

YOUATT.—Works by WILLIAM YOUATT.

THE HORSE. With 52 Wood Engravings. 8vo., 7*s.* 6*d.*

THE DOG. With 33 Wood Engravings. 8vo., 6s.

PHYSIOLOGY, BIOLOGY, ZOOLOGY, ETC.

(And see *MEDICINE AND SURGERY*, page 25.)

ASHBY.—NOTES ON PHYSIOLOGY FOR THE USE OF STUDENTS PREPARING FOR EXAMINATION. By HENRY ASHBY, M.D. Lond., F.R.C.P., Physician to the General Hospital for Sick Children, Manchester; formerly Demonstrator of Physiology, Liverpool School of Medicine. With 148 Illustrations. 18mo., 5*s.*

BARNETT.—THE MAKING OF THE BODY: a Children's Book on Anatomy and Physiology. By Mrs. S. A. BARNETT. With 113 Illustrations. Crown 8vo., 1*s.* 9*d.*

BEDDARD.—Works by FRANK E. BEDDARD, M.A. Oxon.

ELEMENTARY PRACTICAL ZOOLOGY. With 93 Illustrations. Crown 8vo., 2*s.* 6*d.*

THE STRUCTURE AND CLASSIFICATION OF BIRDS. With 252 Illustrations. 8vo., 21*s.* net.

BIDGOOD.—A COURSE OF PRACTICAL ELEMENTARY BIOLOGY. By JOHN BIDGOOD, B.Sc., F.L.S. With 226 Illustrations. Crown 8vo., 4*s.* 6*d.*

BOSE.—RESPONSE IN THE LIVING AND NON-LIVING. By JAGADIS CHUNDER BOSE, M.A. (Cantab.), D.Sc. (Lond.), Professor, Presidency College, Calcutta. With 117 Illustrations. 8vo., 10*s.* 6*d.*

*** *This volume describes experimental investigations on animal, vegetable and inorganic substances regarding their response to stimulus. These researches show that the effects of fatigue, stimulants, depressants and poisons are alike in the organic and inorganic, and demonstrate that the response phenomena in the 'living' have been foreshadowed in the 'non-living'.*

BRODIE. — THE ESSENTIALS OF EXPERIMENTAL PHYSIOLOGY. For the Use of Students. By T. G. BRODIE, M.D., Lecturer on Physiology, St. Thomas's Hospital Medical School. With 2 Plates and 177 Illustrations in the Text. 8vo., 6*s.* 6*d.*

CHAPMAN.—THE FORAMINIFERA: An Introduction to the Study of the Protozoa. By FREDERICK CHAPMAN, A.L.S., F.R.M.S. With 14 Plates and 42 Illustrations in the Text. 8vo., 9*s.* net.

FURNEAUX.—HUMAN PHYSIOLOGY. By W. FURNEAUX, F.R.G.S. With 218 Illustrations. Crown 8vo., 2*s.* 6*d.*

HUDSON AND GOSSE.—THE ROTIFERA, or 'WHEEL-ANIMACULES'. By C. T. HUDSON, LL.D., and P. H. GOSSE, F.R.S. With 30 Coloured and 4 Uncoloured Plates. In 6 Parts. 4to., 10*s.* 6*d.* each. Supplement 12*s.* 6*d.* Complete in 2 vols., with Supplement, 4to., £4 4*s.*

MACALISTER.—Works by ALEXANDER MACALISTER, M.D.

AN INTRODUCTION TO THE SYSTEMATIC ZOOLOGY AND MORPHOLOGY OF VERTEBRATE ANIMALS. With 41 Diagrams. 8vo., 10*s.* 6*d.*

ZOOLOGY OF THE INVERTEBRATE ANIMALS. With 59 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

ZOOLOGY OF THE VERTEBRATE ANIMALS. With 77 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

PHYSIOLOGY, BIOLOGY, ZOOLOGY, ETC.—*Continued.*

MACDOUGAL. — Works by DANIEL TREMBLY MACDOUGALL, Ph.D., Director of the Laboratories of the New York Botanical Garden.

PRACTICAL TEXT-BOOK OF PLANT PHYSIOLOGY. With 159 Illustrations. 8vo., 7*s.* 6*d.* net.

ELEMENTARY PLANT PHYSIOLOGY. With 108 Illustrations. Crown 8vo., 3*s.*

MOORE.—ELEMENTARY PHYSIOLOGY. By BENJAMIN MOORE, M.A., Lecturer on Physiology at the Charing Cross Hospital Medical School. With 125 Illustrations. Crown 8vo., 3*s.* 6*d.*

MORGAN.—ANIMAL BIOLOGY: an Elementary Text-Book. By C. LLOYD MORGAN, F.R.S., Principal of University College, Bristol. With 103 Illustrations. Crown 8vo., 8*s.* 6*d.*

SCHÄFER.—DIRECTIONS FOR CLASS WORK IN PRACTICAL PHYSIOLOGY: Elementary Physiology of Muscle and Nerve and of the Vascular and Nervous Systems. By E. A. SCHÄFER, LL.D., F.R.S., Professor of Physiology in the University of Edinburgh. With 48 Diagrams. 8vo., 3*s.* net.

THORNTON.—Works by JOHN THORNTON, M.A.

HUMAN PHYSIOLOGY. With 267 Illustrations, some Coloured. Crown 8vo., 6*s.*

ELEMENTARY BIOLOGY, Descriptive and Experimental. With numerous Illustrations. Crown 8vo., 3*s.* 6*d.*

BACTERIOLOGY.

CURTIS.—THE ESSENTIALS OF PRACTICAL BACTERIOLOGY: An Elementary Laboratory Book for Students and Practitioners. By H. J. CURTIS, B.S. and M.D. (Lond.), F.R.C.S. With 133 Illustrations. 8vo., 9*s.*

DHINGRA.—AN INTRODUCTION TO BACTERIOLOGY. (Specially designed for Indian Medical Students.) By M. L. DHINGRA, M.D.D.P.H.

FRANKLAND.—MICRO-ORGANISMS IN WATER. Together with an Account of the Bacteriological Methods involved in their Investigation. Specially designed for the use of those connected with the Sanitary Aspects of Water-Supply. By PERCY FRANKLAND, Ph.D., B.Sc. (Lond.), F.R.S., and Mrs. PERCY FRANKLAND. With 2 Plates and Numerous Diagrams. 8vo., 16*s.* net.

FRANKLAND.—BACTERIA IN DAILY LIFE. By Mrs. PERCY FRANKLAND, F.R.M.S. Crown 8vo.

GOADBY.—THE MYCOLOGY OF THE MOUTH: A Text-Book of Oral Bacteria. By KENNETH W. GOADBY, L.D.S. Eng., etc.; Bacteriologist and Lecturer on Bacteriology, National Dental Hospital, etc. With numerous Illustrations. 8vo.

BACTERIOLOGY—*Continued.*

KLÖCKER. — FERMENTATION ORGANISMS IN THE THEORY AND PRACTICE OF THE ALCOHOLIC FERMENTATION INDUSTRY, with special reference to the Construction and Work of Laboratories for the Physiology and Technology of Fermentation. By ALB. KLÖCKER. Translated by G. E. ALLAN, B.Sc., and J. H. MILLAR, F.I.C With 146 Illustrations in the text. 8vo.

BOTANY.

AITKEN. — ELEMENTARY TEXT-BOOK OF BOTANY. By EDITH AITKEN, late Scholar of Girton College. With 400 Diagrams. Crown 8vo., 4*s.* 6*d.*

BENNETT AND MURRAY.—HANDBOOK OF CRYPTOGAMIC BOTANY. By ALFRED W. BENNETT, M.A., B.Sc., F.L.S., Lecturer on Botany at St. Thomas's Hospital; and GEORGE MURRAY, F.L.S., Keeper of Botany, British Museum. With 378 Illustrations. 8vo., 16*s.*

CROSS AND BEVAN.—Works by C. F. CROSS, E. J. BEVAN and C. BEADLE.

CELLULOSE: an Outline of the Chemistry of the Structural Elements of Plants. With Reference to their Natural History and Industrial Uses. With 14 Plates. Crown 8vo., 12*s.* net.

RESEARCHES ON CELLULOSE, 1895-1900. Cr. 8vo., 6*s.* net.

EDMONDS.—Works by HENRY EDMONDS, B.Sc., London.

ELEMENTARY BOTANY. With 342 Illustrations. Cr. 8vo., 2*s.* 6*d.*

BOTANY FOR BEGINNERS. With 85 Illustrations. Fcp. 8vo., 1*s.* 6*d.*

FARMER.—A PRACTICAL INTRODUCTION TO THE STUDY OF BOTANY: Flowering Plants. By J. BRETLAND FARMER, F.R.S., M.A., Professor of Botany in the Royal College of Science, London. With 121 Illustrations. Crown 8vo, 2*s.* 6*d.*

KITCHENER.—A YEAR'S BOTANY. Adapted to Home and School Use. By FRANCES A. KITCHENER. With 195 Illustrations. Cr. 8vo., 5*s.*

LINDLEY AND MOORE.—THE TREASURY OF BOTANY. Edited by J. LINDLEY, M.D., F.R.S., and T. MOORE, F.L.S. With 20 Steel Plates and numerous Woodcuts. Two parts. Fcp. 8vo., 12*s.*

McNAB.—CLASS-BOOK OF BOTANY. By W. R. McNAB.

MORPHOLOGY AND PHYSIOLOGY. With 42 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

CLASSIFICATION OF PLANTS. With 118 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

SORAUER.—A POPULAR TREATISE ON THE PHYSIOLOGY OF PLANTS. By Dr. PAUL SORAUER. Translated by F. E. WEISS, B.Sc., F.L.S. With 33 Illustrations. 8vo., 9*s.* net.

BOTANY—*Continued.*

THOMÉ AND *BENNETT.*—STRUCTURAL AND PHYSIOLOGICAL BOTANY. By OTTO WILHELM THOMÉ and by ALFRED W. BENNETT, B.Sc., F.L.S. With Coloured Map and 600 Woodcuts. Fcp. 8vo., 6*s.*

TUBEUF.—DISEASES OF PLANTS INDUCED BY CRYPTOGAMIC PARASITES. Introduction to the Study of Pathogenic Fungi, Slime Fungi, Bacteria and Algæ. By Dr. KARL FREIHERR VON TUBEUF, Privatdocent in the University of Munich. English Edition by WILLIAM G. SMITH, B.Sc., Ph.D., Lecturer on Plant Physiology, University of Edinburgh. With 330 Illustrations. Royal 8vo., 18*s.* net.

WATTS.—A SCHOOL FLORA. For the use of Elementary Botanical Classes. By W. MARSHALL WATTS, D.Sc. Lond. Cr. 8vo., 2*s.* 6*d.*

AGRICULTURE AND GARDENING.

ADDYMAN.—AGRICULTURAL ANALYSIS. A Manual of Quantitative Analysis for Students of Agriculture. By FRANK T. ADDYMAN, B.Sc. (Lond.), F.I.C. With 49 Illustrations. Crown 8vo., 5*s.* net.

COLEMAN AND *ADDYMAN.*—PRACTICAL AGRICULTURAL CHEMISTRY. By J. BERNARD COLEMAN, A.R.C.Sc., F.I.C., and FRANK T. ADDYMAN, B.Sc. (Lond.), F.I.C. With 24 Illustrations. Crown 8vo., 1*s* 6*d.* net.

HAGGARD.—Works by H. RIDER HAGGARD.

A FARMER'S YEAR: being his Commonplace Book for 1898. With 36 Illustrations by G. LEON LITTLE and three others. Crown 8vo., 7*s.* 6*d.* net.

RURAL ENGLAND: being an Account of Agricultural and Social Researches carried out in the years 1901 and 1902. With 23 Agricultural Maps and 75 Illustrations from Photographs. 2 vols. 8vo., 36*s.* net.

WEATHERS.—A PRACTICAL GUIDE TO GARDEN PLANTS. Containing Descriptions of the Hardiest and most Beautiful Annuals and Biennials, Hardy Herbaceous and Bulbous Perennials, Hardy Water and Bog Plants, Flowering and Ornamental Trees and Shrubs, Conifers, Hardy Ferns, Hardy Bamboos and other Ornamental Grasses; and also the best kinds of Fruit and Vegetables that may be grown in the Open Air in the British Islands, with Full and Practical Instructions as to Culture and Propagation. By JOHN WEATHERS, F.R.H.S., late Assistant Secretary to the Royal Horticultural Society, formerly of the Royal Gardens, Kew, etc. With 163 Diagrams. 8vo., 21*s.* net.

WEBB.—Works by HENRY J. WEBB, Ph.D., B.Sc. (Lond.).

ELEMENTARY AGRICULTURE. A Text-Book specially adapted to the requirements of the Board of Education, the Junior Examination of the Royal Agricultural Society, and other Elementary Examinations. With 34 Illustrations. Crown 8vo., 2*s.* 6*d.*

AGRICULTURE. A Manual for Advanced Science Students. With 100 Illustrations. Crown 8vo., 7*s.* 6*d.* net.

WORKS BY JOHN TYNDALL, D.C.L., LL.D., F.R.S.

LECTURES ON SOUND. With Frontispiece of Fog-Syren, and 203 other Woodcuts and Diagrams in the Text. Crown 8vo., 10*s*. 6*d*.

HEAT, A MODE OF MOTION. With 125 Woodcuts and Diagrams. Crown 8vo., 12*s*.

LECTURES ON LIGHT DELIVERED IN THE UNITED STATES IN 1872 AND 1873. With Portrait, Lithographic Plate, and 59 Diagrams. Crown 8vo., 5*s*.

FRAGMENTS OF SCIENCE: a Series of Detached Essays, Addresses, and Reviews. 2 vols. Crown 8vo., 16*s*.

Vol. I.—The Constitution of Nature—Radiation—On Radiant Heat in Relation to the Colour and Chemical Constitution of Bodies—New Chemical Reactions produced by Light—On Dust and Disease—Voyage to Algeria to observe the Eclipse—Niagara—The Parallel Roads of Glen Roy—Alpine Sculpture—Recent Experiments on Fog-Signals—On the Study of Physics—On Crystalline and Slaty Cleavage—On Paramagnetic and Diamagnetic Forces—Physical Basis of Solar Chemistry—Elementary Magnetism—On Force—Contributions to Molecular Physics—Life and Letters of FARADAY—The Copley Medallist of 1870—The Copley Medallist of 1871—Death by Lightning—Science and the Spirits.

Vol. II.—Reflections on Prayer and Natural Law—Miracles and Special Providences—On Prayer as a Form of Physical Energy—Vitality—Matter and Force—Scientific Materialism—An Address to Students—Scientific Use of the Imagination—The Belfast Address—Apology for the Belfast Address—The Rev. JAMES MARTINEAU and the Belfast Address—Fermentation, and its Bearings on Surgery and Medicine—Spontaneous Generation—Science and Man—Professor VIRCHOW and Evolution—The Electric Light.

NEW FRAGMENTS. Crown 8vo., 10*s*. 6*d*.

CONTENTS.—The Sabbath—Goethe's 'Farbenlehre'—Atoms, Molecules, and Ether Waves—Count Rumford—Louis Pasteur, his Life and Labours—The Rainbow and its Congeners—Address delivered at the Birkbeck Institution on October 22, 1884—Thomas Young—Life in the Alps—About Common Water—Personal Recollections of Thomas Carlyle—On Unveiling the Statue of Thomas Carlyle—On the Origin, Propagation, and Prevention of Phthisis—Old Alpine Jottings—A Morning on Alp Lusgen.

ESSAYS ON THE FLOATING MATTER OF THE AIR IN RELATION TO PUTREFACTION AND INFECTION. With 24 Woodcuts. Crown 8vo., 7*s*. 6*d*.

RESEARCHES ON DIAMAGNETISM AND MAGNECRYSTALLIC ACTION; including the Question of Diamagnetic Polarity. Crown 8vo., 12*s*.

NOTES OF A COURSE OF NINE LECTURES ON LIGHT, delivered at the Royal Institution of Great Britain, 1869. Crown 8vo., 1*s*. 6*d*.

NOTES OF A COURSE OF SEVEN LECTURES ON ELECTRICAL PHENOMENA AND THEORIES, delivered at the Royal Institution of Great Britain, 1870. Crown 8vo., 1*s*. 6*d*.

LESSONS IN ELECTRICITY AT THE ROYAL INSTITUTION 1875-1876. With 58 Woodcuts and Diagrams. Crown 8vo., 2*s*. 6*d*.

THE GLACIERS OF THE ALPS: being a Narrative of Excursions and Ascents. An Account of the Origin and Phenomena of Glaciers, and an Exposition of the Physical Principles to which they are related. With 7 Illustrations. Crown 8vo., 6*s*. 6*d*. net.

HOURS OF EXERCISE IN THE ALPS. With 7 Illustrations. *Crown 8vo.*, 6*s*. 6*d*. net.

FARADAY AS A DISCOVERER. Crown 8vo., 3s. 6d.

TEXT-BOOKS OF SCIENCE.

'HOTOGRAPHY. By Sir WILLIAM DE WIVELESLIE ABNEY, K.C.B., F.R.S. With 134 Illustrations. Fcp. 8vo., 5*s.*

'HE STRENGTH OF MATERIAL AND STRUCTURES. By Sir J. ANDERSON, C.E. With 66 Illustrations. Fcp. 8vo., 3*s.* 6*d.*

RAILWAY APPLIANCES. By Sir JOHN WOLFE BARRY, K.C.B., F.R.S., M.I.C.E. With 218 Illustrations. Fcp. 8vo., 4*s.* 6*d.*

INTRODUCTION TO THE STUDY OF INORGANIC CHEMISTRY. By WILLIAM ALLEN MILLER, M.D., LL.D., F.R.S. With 72 Illustrations. 3*s.* 6*d.*

QUANTITATIVE CHEMICAL ANALYSIS. By T. E. THORPE, C.B., F.R.S., Ph.D. With 88 Illustrations. Fcp. 8vo., 4*s.* 6*d.*

QUALITATIVE ANALYSIS AND LABORATORY PRACTICE. By T. E. THORPE, C.B., Ph.D., F.R.S., and M. M. PATTISON MUIR, M.A. and F.R.S.E. With Plate of Spectra and 57 Illustrations. Fcp. 8vo., 3*s.* 6*d.*

NTRODUCTION TO THE STUDY OF CHEMICAL PHILOSOPHY. By WILLIAM A. TILDEN, D.Sc., London, F.R.S. With Illustrations. Fcp. 8vo., 5*s.* With Answers to Problems. Fcp. 8vo., 5*s.* 6*d.*

ELEMENTS OF ASTRONOMY. By Sir R. S. BALL, LL.D., F.R.S. With 130 Illustrations. Fcp. 8vo., 6*s.* 6*d.*

SYSTEMATIC MINERALOGY. By HILARY BAUERMAN, F.G.S. With 373 Illustrations. Fcp. 8vo., 6*s.*

DESCRIPTIVE MINERALOGY. By HILARY BAUERMAN, F.G.S., etc. With 236 Illustrations. Fcp. 8vo., 6*s.*

METALS: THEIR PROPERTIES AND TREATMENT. By A. K. HUNTINGTON and W. G. MCMILLAN. With 122 Illustrations. Fcp. 8vo., 7*s.* 6*d.*

THEORY OF HEAT. By J. CLERK MAXWELL, M.A., LL.D., Edin., F.R.SS., L. & E. With 38 Illustrations. Fcp. 8vo., 4*s.* 6*d.*

PRACTICAL PHYSICS. By R. T. GLAZEBROOK, M.A., F.R.S., and W. N. SHAW, M.A. With 134 Illustrations. Fcp. 8vo., 7*s.* 6*d.*

PRELIMINARY SURVEY AND ESTIMATES. By THEODORE GRAHAM GRIBBLE, Civil Engineer. Including Elementary Astronomy, Route Surveying, Tacheometry, Curve-ranging, Graphic Mensuration, Estimates, Hydrography and Instruments. With 133 Illustrations. Fcp. 8vo., 7*s.* 6*d.*

ALGEBRA AND TRIGONOMETRY. By WILLIAM NATHANIEL GRIFFIN, B.D. 3*s.* 6*d.* Notes on, with Solutions of the more difficult Questions. Fcp. 8vo., 3*s.* 6*d.*

THE STEAM ENGINE. By GEORGE C. V. HOLMES, Secretary of the Institution of Naval Architects. With 212 Illustrations. Fcp. 8vo., 6*s.*

ELECTRICITY AND MAGNETISM. By FLEEMING JENKIN, F.R.SS., L. & E. With 177 Illustrations. Fcp 8vo., 3*s.* 6*d.*

THE ART OF ELECTRO-METALLURGY. By G. GORE, LL.D., F.R.S. With 56 Illus. Fcp. 8vo., 6*s.*

TELEGRAPHY. By Sir W. H. PREECE, K.C.B., F.R.S., M.I.C.E., and Sir J. SIVEWRIGHT, M.A., K.C.M.G. With 267 Illustrations. Fcp. 8vo., 6*s.*

PHYSICAL OPTICS. By R. T. GLAZEBROOK, M.A., F.R.S. With 183 Illustrations. Fcp. 8vo., 6*s.*

TECHNICAL ARITHMETIC AND MENSURATION. By CHARLES W. MERRIFIELD, F.R.S. 3*s.* 6*d.* Key, by the Rev. JOHN HUNTER, M.A. Fcp. 8vo., 3*s.* 6*d.*

THE STUDY OF ROCKS. By FRANK RUTLEY, F.G.S. With 6 Plates and 88 Illustrations Fcp. 8vo., 4*s.* 6*d.*

WORKSHOP APPLIANCES, including Descriptions of some of the Machine Tools used by Engineers. By C. P. B. SHELLEY, M.I.C.E. With 323 Illustrations. Fcp. 8vo., 5*s.*

ELEMENTS OF MACHINE DESIGN. By W. CAWTHORNE UNWIN, F.R.S., B.Sc., M.I.C.E.

PART I. General Principles, Fastenings and Transmissive Machinery. With 345 Illustrations. Fcp. 8vo., 7*s.* 6*d.*

PART II. Chiefly on Engine Details. With 259 Illustrations. Fcp. 8vo., 6*s.*

STRUCTURAL AND PHYSIOLOGICAL BOTANY. By OTTO WILHELM THOME, and A. W. BENNETT, M.A., B.Sc., F.L.S. With 600 Illustrations. Fcp. 8vo., 6*s.*

PLANE AND SOLID GEOMETRY. By H. W. WATSON, M.A. Fcp. 8vo., 3*s.*

ADVANCED SCIENCE MANUALS.

BUILDING CONSTRUCTION. By the Author of 'Rivington's Notes on Building Construction'. With 385 Illustrations and an Appendix of Examination Questions. Crown 8vo., 4*s.* 6*d.*

THEORETICAL MECHANICS. Solids, including Kinematics, Statics, and Kinetics. By A. THORNTON, M.A., F.R.A.S. With 220 Illustrations, 130 Worked Examples, and over 900 Examples from Examination Papers, etc. Crown 8vo., 4*s.* 6*d.*

HEAT. By MARK R. WRIGHT, Hon. Inter. B.Sc. (Lond.). With 136 Illustrations and numerous Examples and Examination Papers. Crown 8vo., 4*s.* 6*d.*

LIGHT. By W. J. A. EMTAGE, M.A. With 232 Illustrations. Cr. 8vo., 6*s.*

MAGNETISM AND ELECTRICITY. By ARTHUR WILLIAM POYSER, M.A. With 317 Illustrations. Crown 8vo., 4*s.* 6*d.*

INORGANIC CHEMISTRY, THEORETICAL AND PRACTICAL. By WILLIAM JAGO, F.C.S., F.I.C. With Plate of Spectra and 78 Woodcuts. Crown 8vo., 4*s.* 6*d.*

GEOLOGY: a Manual for Stude[nts in] Advanced Classes and for G[eneral] Readers. By CHARLES BIRD, [B.A.] (Lond.), F.G.S. With over 300 [Illus]trations, a Geological Map o[f the] British Isles (coloured), and a [set of] Questions for Examination. C[rown] 8vo., 7*s.* 6*d.*

HUMAN PHYSIOLOGY: a Man[ual for] Students in advanced Classes [of the] Science and Art Department[. By] JOHN THORNTON, M.A. Wit[h ...] Illustrations, some of which [are] Coloured, and a set of Questio[ns for] Examination. Crown 8vo., 6*s.*

PHYSIOGRAPHY. By JOHN TH[ORN]TON, M.A. With 11 Maps, 255 [Illus]trations, and Coloured Map of [Ore] Deposits. Crown 8vo., 4*s.* 6*d.*

AGRICULTURE. By HENRY J. W[EBB,] Ph.D., B.Sc. With 100 Illustra[tions.] Crown 8vo., 7*s.* 6*d.* net.

HYGIENE. By J. LANE NOTTER, [M.A.,] M.D., Professor of Hygiene i[n the] Army Medical School, N[etley;] Colonel, Royal Army Me[dical] Corps; and R. H. FIRTH, F.R.[C.S.,] late Assistant Professor of Hy[giene] in the Army Medical School, N[etley,] Major, Royal Army Medical C[orps.] With 95 Illustrations. Crown [8vo.,] 3*s.* 6*d.*

ELEMENTARY SCIENCE MANUALS.

*** *Written specially to meet the requirements of the ELEMENTARY ST[AGE] OF SCIENCE SUBJECTS as laid down in the Syllabus of the D[irec]tory of the BOARD OF EDUCATION.*

PRACTICAL, PLANE, AND SOLID GEOMETRY, including Graphic Arithmetic. By I. H. MORRIS. Fully Illustrated with Drawings. Crown 8vo., 2*s.* 6*d.*

GEOMETRICAL DRAWING FOR ART STUDENTS. Embracing Plane Geometry and its Applications, the Use of Scales, and the Plans and Elevations of Solids. By I. H. MORRIS. Crown 8vo., 2*s.*

TEXT-BOOK ON PRACTI[CAL,] SOLID, OR DESCRIPTIVE G[EO]METRY. By DAVID ALLAN [LOW] (Whitworth Scholar). Part I. C[rown] 8vo., 2*s.* Part II. Crown 8vo., [...]

AN INTRODUCTION TO MACH[INE] DRAWING AND DESIGN. [By] DAVID ALLAN LOW. With 153 [Illus]trations. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY SCIENCE MANUALS—*Continued.*

[B]UILDING CONSTRUCTION AND DRAWING. By EDWARD J. BURRELL. With 308 Illustrations and Working Drawings. Crown 8vo., 2*s.* 6*d.*

[A]N ELEMENTARY COURSE OF MATHEMATICS. Containing Arithmetic; Euclid (Book I., with Deductions and Exercises); and Algebra. Crown 8vo., 2*s.* 6*d.*

THEORETICAL MECHANICS. Including Hydrostatics and Pneumatics. By J. E. TAYLOR, M.A., B.Sc. With numerous Examples and Answers, and 175 Diagrams and Illustrations. Crown 8vo., 2*s.* 6*d.*

THEORETICAL MECHANICS—SOLIDS. By J. E. TAYLOR, M.A., B.Sc. (Lond.). With 163 Illustrations, 120 Worked Examples, and over 500 Examples from Examination Papers, etc. Crown 8vo., 2*s.* 6*d.*

THEORETICAL MECHANICS—FLUIDS. By J. E. TAYLOR, M.A., B.Sc. (Lond.). With 122 Illustrations, numerous Worked Examples, and about 500 Examples from Examination Papers, etc. Crown 8vo., 2*s.* 6*d.*

A MANUAL OF MECHANICS. With 138 Illustrations and Diagrams, and 188 Examples taken from Examination Papers, with Answers. By T. M. GOODEVE, M.A. Crown 8vo., 2*s.* 6*d.*

SOUND, LIGHT, AND HEAT. By MARK R. WRIGHT, M.A. With 160 Diagrams and Illustrations. Crown 8vo., 2*s.* 6*d.*

METALLURGY: an Elementary Text-Book. By E. L. RHEAD. With 94 Illustrations. Crown 8vo., 3*s.* 6*d.*

PHYSICS. Alternative Course. By MARK R. WRIGHT, M.A. With 242 Illustrations. Crown 8vo., 2*s.* 6*d.*

MAGNETISM AND ELECTRICITY. By A. W. POYSER, M.A. With 235 Illustrations. Crown 8vo., 2*s.* 6*d.*

PROBLEMS AND SOLUTIONS IN ELEMENTARY ELECTRICITY AND MAGNETISM. By W. SLINGO and A. BROOKER. Embracing a Complete Set of Answers to the South Kensington Papers for the years 1885-1899, and a Series of Original Questions. With 67 Original Illustrations. Crown 8vo., 2*s.*

ORGANIC CHEMISTRY: the Fatty Compounds. By R. LLOYD WHITELEY, F.I.C., F.C.S. With 45 Illustrations. Crown 8vo., 3*s.* 6*d.*

INORGANIC CHEMISTRY, THEORETICAL AND PRACTICAL. By WILLIAM JAGO, F.C.S., F.I.C. With 63 Illustrations and numerous Questions and Exercises. Fcp. 8vo. 2*s.* 6*d.*

AN INTRODUCTION TO PRACTICAL INORGANIC CHEMISTRY. By WILLIAM JAGO, F.C.S., F.I.C. Crown 8vo., 1*s.* 6*d.*

PRACTICAL CHEMISTRY: the Principles of Qualitative Analysis. By WILLIAM A. TILDEN, D.Sc. Fcp. 8vo., 1*s.* 6*d.*

ELEMENTARY INORGANIC CHEMISTRY. By WILLIAM FURNEAUX, F.R.G.S. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY GEOLOGY. By CHARLES BIRD, B.A., F.G.S. With Coloured Geological Map of the British Islands, and 247 Illustrations. Crown 8vo., 2*s.* 6*d.*

HUMAN PHYSIOLOGY. By WILLIAM FURNEAUX, F.R.G.S. With 218 Illustrations. Crown 8vo., 2*s.* 6*d.*

A COURSE OF PRACTICAL ELEMENTARY BIOLOGY. By J. BIDGOOD, B.Sc. With 226 Illustrations. Crown 8vo., 4*s.* 6*d.*

ELEMENTARY BOTANY, THEORETICAL AND PRACTICAL. By HENRY EDMONDS, B.Sc. With 342 Illustrations. Crown 8vo, 2*s.* 6*d.*

STEAM. By WILLIAM RIPPER, Member of the Institution of Mechanical Engineers. With 185 Illustrations. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PHYSIOGRAPHY. By J. THORNTON, M.A. With 13 Maps and 295 Illustrations. With Appendix on Astronomical Instruments and Measurements. Crown 8vo., 2*s.* 6*d.*

AGRICULTURE. By HENRY J. WEBB, Ph.D. With 34 Illustrations. Crown 8vo., 2*s.* 6*d.*

THE LONDON SCIENCE CLASS-BOOKS.

Edited by G. CAREY FOSTER, F.R.S., and by Sir PHILIP MAGNUS, B.Sc., B.A., of the City and Guilds of London Institute.

ASTRONOMY. By Sir ROBERT STAWELL BALL, LL.D., F.R.S. With 41 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

MECHANICS. By SIR ROBERT STAWELL BALL, LL.D., F.R.S. With 89 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

THE LAWS OF HEALTH. By W. H. CORFIELD, M A., M.D., F.R.C.P. With 22 Illustrations. Fcp. 8vo., 1*s.* 6*d.*

MOLECULAR PHYSICS AND SOUND. By FREDERICK GUTHRIE, F.R.S. With 91 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

GEOMETRY, CONGRUENT FIGURES. By O. HENRICI, Ph.D., F.R.S. With 141 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

ZOOLOGY OF THE INVERTEBRATE ANIMALS. By ALEXANDER MACALISTER, M.D. With 59 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

ZOOLOGY OF THE VERTEBRATE ANIMALS. By ALEXANDER MACALISTER, M.D. With 77 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

HYDROSTATICS AND PNEUMATICS. By Sir PHILIP MAGNUS, B.Sc., B.A. With 79 Diagrams. Fcp. 8vo., 1*s.* 6*d.* (To be had also *with Answers*, 2*s.*) The Worked Solutions of the Problems. 2*s.*

BOTANY. Outlines of the Classification of Plants. By W. R. MCNAB, M.D. With 118 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

BOTANY. Outlines of Morphology and Physiology. By W. R. MCNAB, M.D. With 42 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

THERMODYNAMICS. By RICHARD WORMELL, M.A., D.Sc. With 41 Diagrams. Fcp. 8vo., 1*s.* 6*d.*

PRACTICAL ELEMENTARY SCIENCE SERIES.

ELEMENTARY PRACTICAL PHYSIOGRAPHY. (Section I.) By JOHN THORNTON, M.A. With 215 Illustrations and a Coloured Spectrum. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PRACTICAL PHYSIOGRAPHY. (Section II.). A Course of Lessons and Experiments in Elementary Science for the Queen's Scholarship Examination. By JOHN THORNTON, M.A. With 98 Illustrations and a Series of Questions. Crown 8vo., 2*s.* 6*d.*

PRACTICAL DOMESTIC HYGIENE. By J. LANE NOTTER, M.A., M.D., and R. H. FIRTH, F.R.C.S. With 83 Illustrations. Crown 8vo., 2*s.* 6*d.*

A PRACTICAL INTRODUCTION TO THE STUDY OF BOTANY: Flowering Plants. By J. BRETLAND FARMER, F.R.S., M.A. With 121 Illustrations. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PRACTICAL HYGIENE. Section I. By WILLIAM S. FURNEAUX. With 146 Illustrations. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PRACTICAL SOUND, LIGHT, AND HEAT. By JOSEPH S. DEXTER. With 152 Illustrations. Crown 8vo., 2*s.* 6*d.*

PRACTICAL MATHEMATICS. By A. G. CRACKNELL, M.A., B.Sc. Crown 8vo., 3*s.* 6*d.*

ELEMENTARY PRACTICAL CHEMISTRY. By G. S. NEWTH, F.I.C., F.C.S. With 108 Illustrations and 254 Experiments. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PRACTICAL PHYSICS. By W. WATSON, D.Sc. With 120 Illustrations and 193 Exercises. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY PRACTICAL ZOOLOGY. By FRANK E. BEDDARD, M.A. Oxon., F.R.S. With 93 Illustrations. Crown 8vo., 2*s.* 6*d.*

ELEMENTARY BIOLOGY. By JOHN THORNTON, M.A. With 108 Illustrations. Crown 8vo., 3*s.* 6*d.*

THE ELEMENTS OF GEOMETRICAL DRAWING: an Elementary Text-book on Practical Plane Geometry, including an Introduction to Solid Geometry. By HENRY J. SPOONER, C.E., M.Inst.M.E. Crown 8vo., 3*s.* 6*d.*

5,000/11. 02.